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SCIENTIFIC MONTHLY



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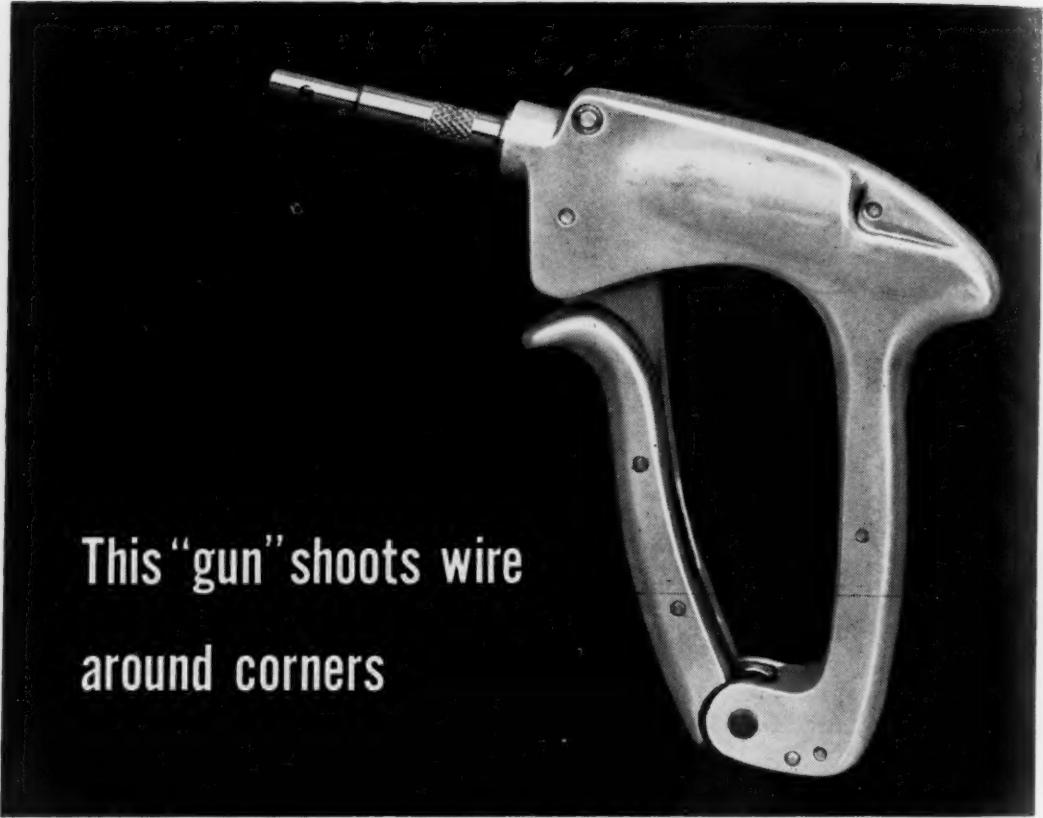
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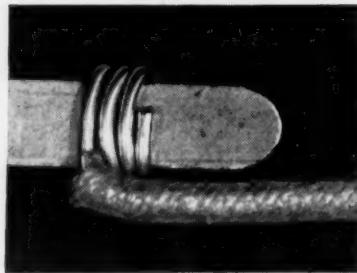
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MONTHLY



This "gun" shoots wire around corners



*Close-up of connection made with new
tool—neat, tight windings.*

IT DOESN'T take long to wrap *one* wire around a terminal and snip off the end. But *hundreds of millions* of such connections are being made each year.

Now this job is done much more efficiently with a new wire wrapping tool invented at Bell Laboratories. This "gun" whisks wire tightly around terminals before solder is applied. The connection is better and there is no waste wire.

The hand-operated wrapper shown here is for the telephone man's tool kit. Power-driven wrappers developed by Western Electric, manufacturing unit of the Bell System, are speeding the production of telephone equipment. The gun's small nozzle reaches where fingers couldn't—a big advantage these days when parts are made smaller as well as better.

Bell Telephone Laboratories scientists devise many special tools to help your telephone system meet growing demands—and keep your telephone service one of today's best bargains.

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THE SCIENTIFIC MONTHLY

VOL. LXXII

MAY 1951

NO. 5

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Established 1872 as *The Popular Science Monthly*; since 1915 an official publication of the American Association for the Advancement of Science.

Publication office, Business Press, Inc., 10 McGovern Ave., Lancaster, Pa. Orders for subscriptions and requests for change of address should be directed to the Circulation Department, A.A.S., 1515 Massachusetts Ave., N.W., Washington 5, D. C. Subscriptions: \$7.50 per year; single copies 75 cents. Four weeks are required to effect change of address.

Address all correspondence concerning editorial matters and advertising to THE SCIENTIFIC MONTHLY, 1515 Massachusetts Ave., N.W., Washington 5, D. C. The editors are not responsible for

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Science and Technology

(From the Month's News Releases)

Remote Control

A device for remote pipetting of radioactive liquids to perform all the necessary operations without the necessity of handling the pipette at any stage of its use can be employed with pipettes ranging from 100 up to 5 ml. The instrument is made almost entirely of aluminum and weighs only $\frac{1}{8}$ pound.

Five Miles of Writing

The Handee-Marker marks any surface in fine or bold letters in a choice of eight colors. Leakproof bottle and a visible ink supply, inexpensively replaced, are features.

Save the Surface and You Save All

Neoprene, the synthetic rubber, can be applied by brush or spray gun in a single coat of 5-10 mils thickness as an airdry protective coating. Outstanding properties are exceptional resistance to oil, grease, and chemicals and age-cracking by sunlight, weather, and ozone. Neoprene also possesses the usual characteristics of any natural rubber product.

New Tapes

A luminescent, moistureproof packaging tape can be seen from a distance of several feet. Useful in blackout areas, it may also be utilized to seal and mark boxes and containers of all sizes and shapes or put on any object that must be readily identified in the dark. While not in use the adhesive is protected by a covering, easily stripped off.

Now you may identify your personal property by using handy stick-on tape that comes in rolls of the familiar cellulose acetate film, with your name and address imprinted.

A sealing tape made of two layers of kraft paper interlined with rayon yarn comes in six widths and has a water-resistant asphalt coating.

Ideal Mop

A mop made of cellulose sponge yarn can be wrung out by twisting the top of the handle. This keeps the hands dry, and in addition the yarn absorbs two to three times as much water as ordinary mops, rinses clean, and does not develop a sour odor.

Find That Leak

Leaks too small to be detected by the usual obvious signs, can be discovered in vacuum systems down to 1μ Hg by use of the principle that the tendency of hot platinum to emit positive ions is greatly stimulated by the tiniest trace of halogens or their compounds. A new sensitive leak detector for this purpose is especially useful for those who have only occasional need for such a device.

Cheese Research

The USDA Bureau of Dairy Industry has recently developed hydrolyzed whey protein (suitable for use in cheese spreads), a smooth bland product converted by a commercial enzyme into an excellent-tasting product that compares favorably in food value with cream cheese. One

hundred pounds of whey yield about five pounds of whey protein, and no special equipment is needed for its manufacture in a cheese factory.

Easy Positioning

Lab-Lift is a device with a platform that can be adjusted to any point from 11 to $18\frac{1}{2}$ inches above the workbench by the turn of a screw. According to the manufacturer, it is more stable and easier to operate than previous models or makeshift devices. Heavy kettles, reaction flasks, cold and hot baths, and similar vessels may be held safely on Lab-Lift or moved up or down to be attached to, or removed from, reaction trains, etc.

Bismuth Wire

Bismuth wire and ribbon said to be ductile enough to wind on its own diameter at about 70° F., although of low tensile strength, will permit engineers to make useful commercial applications of the unique electrical properties of this material.

Button Gauge

A plastic sewing aid, weighing only a little over an ounce, has one end for small buttons, the other for large, and can be used also for removing basting threads, forming collar points, measuring hems and tucks, or removing lint and dust.

Perfect Awnings at Last

Awnings colored with vinylite resin-based paints are claimed by the manufacturers to be resistant to moisture, mould, mildew, abrasion, and most chemicals. Resistance to ultraviolet rays make them nearly fadeproof, there is no oxidation and powdering of pigment, and they are easy to put up and take down. Available in many styles and sizes, as well as custom-made.

You Can't Rock It

A 6-foot inflatable lightweight boat, with water-filled pontoons, is stable in rough water and steady on its course when paddled. Of plastic sheeting, it is resistant to salt water, oils, grease, temperature changes, and abrasion. About \$25.00.

No More Moths

A nonvolatile product that permanently moth- and fire-proofs closets, chests, and drawers also has insecticidal and deodorizing properties. A powder, it is sold in 5- and 10-lb. cans and, mixed with water, may be painted or sprayed on any surface, including wallpaper. It will, says the manufacturer, dry to a hard coat that may be planed or sawed and that will take nails or screws.

Data Handling Expedited

An electronic device that will read test instruments at speeds up to 50,000 readings per second and record them on tape or punched cards ready for computation is expected to eliminate a good deal of cumbersome mental work. The unit is $20'' \times 30'' \times 5''$, operates from 110-125 volts, and is easily incorporated into a variety of multiple-instrument reading and recording systems.

THE SCIENTIFIC MONTHLY

MAY 1951

The Sea Lamprey in the Great Lakes

VERNON C. APPLEGATE

The author, who is in charge of the sea lamprey investigations of the Fish and Wildlife Service, U. S. Department of the Interior, joined the staff of Great Lakes Fishery Investigations in 1950. His present studies are in effect a continuation of researches begun in 1947 when he was employed as a fishery research biologist with the Institute for Fisheries Research, Michigan Department of Conservation. Earlier, Dr. Applegate was biologist with the International Pacific Salmon Fisheries Commission and teaching assistant in the Department of Zoology, University of Michigan, where he took his Ph.D. in 1950.

THE sea lamprey (*Petromyzon marinus*) is typically anadromous; that is, it hatches and spends its early life in fresh water, migrates to the ocean, where it grows to maturity, and returns to fresh water to spawn. It is during its life in the ocean that it is parasitic on fish. Sea lampreys have long been known in the streams of our Atlantic coast, where they have been taken as far south as northern Florida. In common with certain other anadromous species, the sea lamprey has adjusted itself in some areas to spending its entire life cycle in fresh water. It is native, for example, in Lake Ontario and in some lakes of northern New York.

Prior to the construction of the Welland Canal in 1829, Niagara Falls stood as a barrier to the spread of the sea lamprey from Lake Ontario to the other Great Lakes. Even after the completion of the canal, the lamprey seems to have been slow to take advantage of the route, for the first speci-

men to be taken above the falls was captured in 1921, nearly a century later, in Lake Erie off Merlin, Ontario. It is possible, of course, that sea lampreys straggled through the canal repeatedly but were not seen or captured. The first known spawning population of the sea lamprey was discovered in 1932 in the Huron River, a tributary of Lake Erie.

The sea lamprey has never been able to establish itself in great numbers in Lake Erie, but, once it reached Lake Huron, its spread and increase in abundance were rapid. Well before the end of the 1930s Lake Huron fishermen began to complain of the increasing frequency of scarred lake trout in their catches and the deterioration in the quality of lake trout fishing. They expressed a grave fear that this parasite might completely destroy the fishery for the species.

That this fear was well grounded was borne out by subsequent experience. The speed and the com-

pleness of the collapse of the lake trout fishery in Lake Huron are demonstrated by the record (Table 1) of the catch in United States waters from 1935 through 1949. The production figure for every year after 1939 set a new record low.

The first sea lamprey known to have been captured in Lake Michigan was taken off Milwaukee in 1936. The rapid increase in abundance of the sea lamprey and the decline of the lake trout got under way later in Lake Michigan than in Lake Huron, but aside from this difference of timing the trends have been much the same. How similar the course of the decline of the lake trout fishery in the two lakes has been is evident from the comparisons of the record of production in Lake Michigan with that for the same years in Lake Huron (Table 2). In Lake Michigan the series of record-low years began with 1947.

A few individuals not acquainted with the trends of the lake trout fishery have suggested that the catastrophes that have overtaken Lake Huron and Lake Michigan were the result of overfishing, and hence that the present distress of the industry is but just retribution for a wanton and destructive exploitation of the stocks. Complete and detailed statistics, beginning with 1929, on the actual quantities of gear lifted that produced lake trout demonstrate conclusively, however, that overfishing could not have brought about the collapse in the lake trout fishery in the United States waters of Lake Huron or in the state of Michigan waters of Lake Michigan. Fishing pressure in both areas tended to be below the modern average in the years immediately preceding and during the recent decline. The outside possibility that some obscure and altogether unsuspected factor may have destroyed the lake trout populations of Lakes Huron and Michigan cannot be ignored, but the most careful consideration of available evidence nevertheless permits only one conclusion—namely, that the sea

TABLE 1

YEAR	POUNDS
1935	1,743,000
1936	1,400,000
1937	1,340,000
1938	1,270,000
1939	1,372,000
1940	940,000
1941	892,000
1942	728,000
1943	459,000
1944	363,000
1945	173,000
1946	38,000
1947	12,000
1948	4,000
1949	1,000

TABLE 2

YEAR	POUNDS
1935	4,873,000
1936	4,763,000
1937	4,988,000
1938	4,906,000
1939	5,660,000
1940	6,266,000
1941	6,784,000
1942	6,484,000
1943	6,860,000
1944	6,498,000
1945	5,437,000
1946	3,974,000
1947	2,425,000
1948	1,196,000
1949	343,000

lamprey was the major, perhaps the only significant, cause of the decrease of the lake trout in both lakes.

At prevailing market prices the actual loss of cash income to the commercial fishermen of Lakes Huron and Michigan resulting from the decreases in the take of lake trout amounts to approximately \$3,500,000. At a 4 per cent interest rate this figure represents the annual return from a capital investment of \$87,500,000. When one considers how greatly the decrease of income to wholesalers and retailers of fish, to transportation companies, and to manufacturers of fishing equipment and supplies adds to the above value, and remembers also that no estimate is included for species other than lake trout that have been harmed by the sea lamprey, the real gravity of the economic losses and the urgent need of sparing no effort to bring the parasite under control become even more obvious.

The sea lamprey was first reported from Lake Superior in 1945. Although specimens have been taken as far west as Minnesota, and spawning runs have been discovered as far west as Marquette, Michigan, lampreys have become plentiful only in the extreme eastern end. Any effects on the lake trout fishery, therefore, have been only local. Correspondingly, the production of lake trout in Lake Superior has held up, as statistics for United States waters prove (Table 3).

We should not be too ready to take comfort from these production figures for Lake Superior, first, because records prove that the catch per net is declining, and the yield has been maintained in recent years only by greatly increased fishing pressure, and, second, because experience in Lake Huron, and especially in Lake Michigan, proves that complete collapse of a fishery can take place in only a few years.

In both Lake Huron and Lake Michigan the attacks by sea lampreys on other species increased

as the numbers of lake trout decreased. Although the injury to stocks so far has not been as great for other fish as for lake trout, the damage to some varieties, particularly whitefish, suckers, and walleyes, obviously is heavy and is increasing to an alarming extent in some waters. Seemingly all commercial species are subject to some lamprey depredations.

Life History of the Sea Lamprey

Knowledge of the enemy is essential to the waging of a successful war; hence, information on the natural history of the sea lamprey is vital if we are to ascertain the vulnerable points in its life cycle. During the past several years researches sponsored by the state of Michigan and, more recently, by the Fish and Wildlife Service have added greatly to our information on this parasite. The following account is based largely on these investigations. For purposes of description the life cycle may be divided into two periods—stream life and lake life.

Mature sea lampreys enter the streams tributary to the Great Lakes for the purpose of spawning in late spring and early summer. This spawning migration extends over as many as sixteen weeks. Temperature is a major controlling factor over the upstream movements; heavy runs do not begin until the stream temperature reaches 50° F. If the temperature drops below that point, the run slacks off. There is evidence that lampreys are unable to spawn in streams that are too cold. They may enter them but they later return to the lake to seek another stream.

For successful nest building the sea lamprey requires a bottom of coarse gravel and rubble in an area with a moderately strong current. Seizing stones with their suckerlike mouths, the sea lampreys build crescent-shaped nests. If the grounds are extensive in relation to the size of the spawning



U. S. Fish and Wildlife photo

Mouth of sea lamprey of the Great Lakes.

population, the nests usually are well spaced within the stream. If the grounds are congested, the nests are closely grouped, and on occasion portions of the spawning areas are reworked by late arrivals.

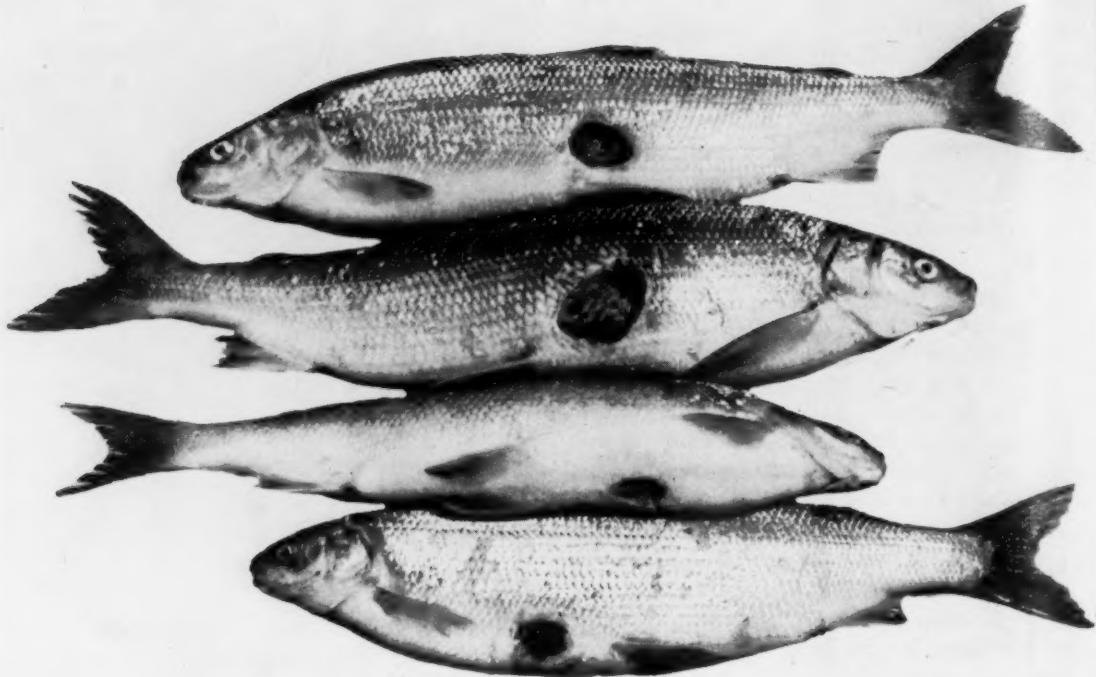
When the eggs are extruded by the female and fertilized by the male, they are carried by the current into the gravel of the nests, where they develop and hatch in ten to twelve days, depending on temperature conditions. A single female may deposit as many as 107,000 eggs; the average number is about 61,500. The sea lamprey spawns only once. All adults die soon after they complete spawning.

When the recently hatched larvae emerge from the nest, they drift downstream until they reach mud and silt flats. Here they dive for the bottom, where each establishes itself in its individual burrow. The food, which is sucked in from the water passing the mouth of the burrow, consists largely of microscopic organisms that live in the surface film of the stream bottom. During the stream life the young lampreys are completely harmless. According to our best evidence, the length of the larval life is about four years. During the final season in the stream the larvae begin to transform into the adult parasitic stage. Once the transformation is completed, they emerge from the mud flats and drift lakeward.

The newly transformed larvae range from 3.7 to 7.2 inches long and average 5.7 inches. The downstream movement always occurs at a time of rising water levels. Some of the young lampreys leave the streams in the late fall, and a few migrate

TABLE 3

YEAR	POUNDS
1935	3,476,000
1936	3,234,000
1937	3,085,000
1938	3,167,000
1939	2,744,000
1940	2,677,000
1941	2,854,000
1942	2,959,000
1943	3,053,000
1944	3,740,000
1945	3,369,000
1946	3,444,000
1947	2,964,000
1948	2,954,000
1949	2,965,000



Four lamprey-scarred whitefish taken by a commercial fisherman in northern Lake Huron.

at various times during the winter, but the major downstream movement occurs at the time of breakup in the spring. When the young sea lampreys reach the lake they are ready to begin their parasitic existence.

During the parasitic phase of its life, the sea lamprey feeds on the blood and body juices of fish. It attaches itself to its victim by means of its sucker-like mouth and with its sharp teeth rasps a hole in the body. Lampreys kept in aquaria will remain attached to fish as long as three weeks, provided the victim does not die. These same aquarium experiments proved that delicate species such as the brook trout are killed quickly, but that more hardy fish such as bullheads may survive attacks by several lampreys over a period of weeks.

Details on the life of the sea lamprey in the lake are scanty. Measurements of a considerable number of specimens indicate that the average time in the lake is about one and one half years. (An experiment currently in progress, on rearing sea lampreys in aquaria, supports this estimate.) There is some evidence also that the newly transformed sea lampreys migrate first to deep water, where they attack lake trout, chubs, and other deep-water species. As the lampreys grow larger,

they move shoreward and in the fall are to be found in relatively shallow water. It is at this time that attacks on whitefish, suckers, and other shallow-water fish reach their maximum.

Toward the end of winter and in early spring the sea lampreys begin to congregate in estuaries off the mouths of streams. During this waiting period preceding the spawning migration, tremendous internal changes occur. The sex glands expand enormously, and the digestive tract and other organs shrink. As a result of these changes the lamprey becomes incapable of feeding. The process of deterioration extends even to the musculature and skin. At the time of this general breakdown the lamprey is subject to extensive attacks by fungus.

Program for the Control of the Sea Lamprey

According to the present state of our knowledge, the most vulnerable period in the sea lamprey's life cycle occurs in the stream. Attacks on lampreys in the streams have been organized along three lines: prevention of spawning through the blocking of the stream and/or the capture and destruction of lampreys en route to the spawning grounds; the destruction of larval lampreys before

they emerge from the mud and silt flats; the destruction of the newly transformed migrants en route to the lake. Of the three approaches, the first and third appear to offer the greatest promise. It is nevertheless planned to develop and test procedures along all lines. Nothing that has even an outside chance of yielding positive results will be ignored.

Prevention of spawning. Tests are in progress or planned on a variety of weirs, traps, barrier dams, and sonic and electrical devices as a means of capturing or destroying spawning-run sea lampreys or of preventing their movement upstream. In many streams this type of operation is handicapped severely by the necessity for avoiding injury to runs of such valuable food and game fish as suckers, northern pike, walleyes, and rainbow trout. This limitation makes it impossible, for example, to apply electrical charges that might prove lethal to lampreys, or to bar passage upstream unless equipment can be developed that will block or kill the lamprey without blocking or greatly injuring fish. Similarly, weirs need to be equipped with traps so that fish can be passed up- or downstream while the lampreys are removed and destroyed. Barrier dams need similar traps unless they can be so constructed that they will block the

lampreys but are still low enough to be jumped by fish.

Devices that prevent the spawning of sea lampreys offer a positive method of attack, but they have one great drawback—the tremendous cost of installation and operation in the many scores of streams that contain lamprey runs. The installation of weirs in small streams is not extremely expensive, but the larger weirs cost many thousands of dollars. Furthermore, these structures require regular and frequent attention and service if they are to be operated efficiently. A second difficulty with control based on the blocking or destruction of spawning-run sea lampreys lies in the circumstance that the benefits from these activities are long deferred. Since the larval life is approximately four years long, and the length of the parasitic phase averages approximately eighteen months, results from the blocking of runs cannot become apparent until more than five years have elapsed.

Destruction of larval sea lampreys. The destruction of the larval lampreys offers the advantage that as many as four generations of young can be eliminated at one time and results can accordingly be expected in less than two years. The practical difficulties, however, are enormous. In most waters the larval beds are widely scattered throughout



Sea lamprey weir in the Ocqueoc River, a tributary of northern Lake Huron. The cost of constructing this weir was \$13,000; annual expenses for maintenance and operation amount to about \$4,000.

the stream. Some of the larger beds can be attacked, but the lampreys settle down in such small patches of silt (as those commonly to be seen on the downstream side of deadheads) that to locate and treat all of them is not feasible. Because of this wide scattering the mechanical destruction of larval lampreys in silt beds does not seem practicable. Killing by electrical current has been considered, but the results with equipment tested to date have not been promising. The chemical treatment of larval beds offers some promise if we can solve the problem of poisoning the lampreys without making the stream water so toxic as to be lethal to fish. Experiments on the reactions of larval sea lampreys to various toxicants are now in progress.

Thought has been given also to the possibility of introducing animals that might prey on larval sea lampreys. In this connection the American eel gives some promise. Tests conducted in aquaria have demonstrated that eels will attack and destroy larvae, but whether similar results can be obtained under natural conditions remains to be determined. It is important also to make certain that any eels that might be introduced will not prove harmful to native fish.

Destruction of newly transformed sea lampreys. The downstream migration of newly transformed larvae in the winter constitutes a period in the life cycle of the lamprey which offers even greater

possibilities for destruction than the time of the upstream spawning migration. At this time of year the movements of fish are at a minimum. Consequently, equipment that kills any organisms passing along the stream inflicts only negligible damage on animals other than lampreys.

Experiments have demonstrated that downstream migrants can be taken readily by means of a dam and inclined-screen trap, but this equipment is expensive to construct and requires regular attention. Furthermore, the topography of many streams does not lend itself to this type of structure. Far more promising are electrical installations that send a current through the stream sufficiently strong to kill the lampreys as they drift by. Attention is being concentrated on the development of apparatus that will give the greatest effectiveness at minimum cost. These devices must be so constructed as to be safe and to need only occasional inspection and service. Preliminary experiments have indicated that young lampreys are extraordinarily resistant to electrical currents, that the construction of a lethal device will be much more difficult than was anticipated, and that the operation may prove prohibitively costly.

The Outlook for Control

Biology, engineering, and economics—all of these must enter into our consideration when we speculate as to the possibility of developing a program



Inclined-screen trap at a dam in the Carp Lake River, a tributary of the Straits of Mackinac. This device proved effective in trapping the downstream runs of young, recently transformed sea lampreys. The aggregate cost of the dam and trap was about \$6,000; annual maintenance and operation costs are about \$3,000.

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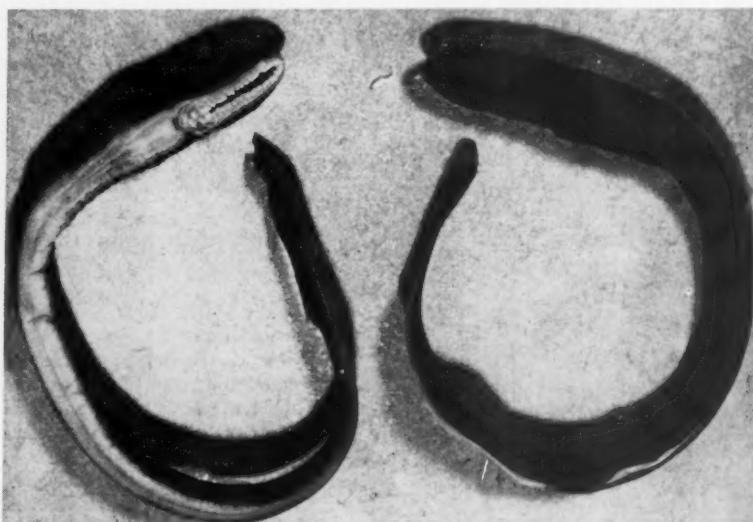
Removing spawning-run sea lampreys from a weir trap in the Ocqueoc River.

for the effective control of the sea lamprey in the upper Great Lakes. The available information on the life cycle of the sea lamprey is sound and sufficiently extensive to serve as a basis for the initia-

tion of control procedures. Certain aspects of the predator's natural history need to be explored further so that we may judge better the most vulnerable points in its career. Only through more detailed knowledge is the maximum efficiency to be obtained.

Economic considerations dictate that no effort be spared to accomplish the greatest destruction of sea lampreys at the least cost. If cost were no object, control might easily prove to be relatively simple. However, a control program that could be maintained at an annual figure approximating or exceeding the potential value of the fisheries could not be termed sound. Major effort is to be directed, therefore, toward the development of more and more destructive devices that will call for less and less expense in installation and maintenance. The success or failure of attempts to control the sea lamprey well may be determined by the success or failure in the development of procedures the cost of which can be economically justified. There can be little doubt that the most effective control of the lamprey will be accomplished by a variety of procedures, each adapted to serve best under special local conditions.

Control of the sea lamprey will not be accomplished either in a short time or easily or cheaply. Furthermore, the control measures will need to be established on a continuing basis. The prospects for the eradication of this predator are so meager that they should not enter into our consideration in setting up a control program. We cannot hope for an immediate solution of the sea lamprey problem and a rapid return of the fisheries to their former productivity.



U. S. Fish and Wildlife photo

Newly transformed sea lamprey, taken in weir on the Ocqueoc River, on its way to Lake Huron to begin parasitic existence.

Scientists and Education

SIMON WILLIAMS and JAMES D. LAURITS

Of the 248 letters received by the editors and the author, 226 were enthusiastically for and 22 bitterly against Dr. Fuller (SCI. MONTHLY, 72, 32 [1951]). Members of the staffs of several schools of education offered articles in reply. We have chosen the one presented here as the best-tempered and the most representative and, in fairness to the authors, have restrained every impulse to wield the blue pencil. Simon Williams is lecturer in general education at Harvard, and James D. Laurits is assistant to the dean. Dr. Williams is a former director of research, National Cotton Council of America, Memphis, former associate director of research, Fabric Research Laboratories, Boston, and former dean, Lowell Textile Institute, Lowell, Massachusetts. Mr. Laurits is a Yale graduate engineer and a former mathematics instructor in the Elgin (Ill.) High School. Both authors were Fellows in education at Harvard during 1949-50.

THIS article is a reaction to the attack on modern education by H. J. Fuller, "The Emperor's New Clothes, or *Prius Dementat*," which appeared in the January 1951, issue of THE SCIENTIFIC MONTHLY. A response is deemed imperative, for however humorously Fuller may have cloaked his criticism and however valid certain of his arguments may have been, the distorting intensity of his words and the questionable quality of his so-called "bits of evidence" can only serve to further befog and bemuse efforts to understand the nature of the educational problem in the United States.

Many of Fuller's points we will comment on or answer directly, although too briefly; we do not here repeat his challenges. The other charges would automatically be dissolved by a look at accumulated evidence on which we offer a beginning. However, a blow-by-blow rebuttal is impossible without a book-length manuscript on data alone, *without* the regrettable educational jargon. The connotation is clear—had Fuller known the field, had he supported his arguments with evidence, had his analysis been objective, then he could not have covered the whole of education as he did in his jaunty emotional tour. Thus, persons who wish to be honest and thorough might be driven near to distraction at the task of plugging the holes made by easy heedlessness.

Let us state at the outset that this is not an attempt to whitewash education. We agree and practically all educators agree that many aspects of our educational system are deserving of criticism. We are all deeply concerned with the success or failure of education and no doubt many have felt a heart-

pounding sympathy with A. N. Whitehead, who began the conclusion to his notable essay, "The Aims of Education," with these words:

When one considers in its length and in its breadth the importance of this question of the education of a nation's young, the broken lives, the defeated hopes, the national failures, which result from the frivolous inertia with which it is treated, it is difficult to restrain within oneself a savage rage.

But are we equally agreed that this savage rage best contributes its energy to the solution of educational problems by conversion into a stream of invective (such as poured out of Fuller's pen)? If scientists are going to become vocal on the subject of education, then we must take vigorous exception to methods which involve mere personal outbursts as those to be adopted by members of such groups as AAAS, Sigma Xi, and Phi Beta Kappa, all well represented in the schools of education.

On good behavior. In matters concerning our children, our personal beliefs, our way of life, the warfare of the heart and the head is always at maximum intensity. I. A. Richards, in his *How to Read a Page*, gives a brilliant analysis of this type of internal conflict, in which he uses an image from John Donne, *Satyre III*:¹

Doubt wisely; in strange way
To stand inquiring right, is not to stray;
To sleepe, or runne wrong is. On a huge hill,
Cragged and steep, Truth stands, and hee that will
Reach her, about must, and about must goe;
And what the hills suddennes resists, winne so.

For the seeker of truth, Donne's picture may not be comforting, but it is the image out of which science has built its strength. Wise doubt and a rigorous, austere demand on any evidence of truth

are part of the professional ethics of any field of science. This is no less true of the fields of social science, scarcely born, than of the older fields of natural science. It should be true of the behavior of any kind of scientist when he examines the progress in another field with which he may be emotionally and intellectually involved but in which he has not had the time to train and practice. It is always a puzzling experience to observe a scientist, who in his own research would no doubt adhere to the most rigid demands on experimental data, turn about and blast a field with which he has a minimum of familiarity, on the basis of the flimsiest, indefensible evidence, largely of the "I knew a man" type.

It is confusing, contradictory, and intolerable for men in the older fields of science, whose progress has depended upon generations of wise doubt, free inquiry, and a vigorous experimental approach in the face of all difficulties, to turn to United States education, one of the most far-reaching experiments ever to be attempted, and in essence say: Look backward; quit this experimental nonsense; cease this disturbing inquiry into the learning processes and into new methods of teaching; disregard the evidence of the psychologist, the sociologist, the anthropologist, the biometrician; all that has gone before is good and true, what I did is good enough for my children; what I don't understand and cannot take the time to understand is of no value and of evil, destructive import.

Schools of education are here to stay. They can and have fulfilled a need. If they are weak, as many schools are, let us unite to build their strength. Learning experiments are here to stay; every assumption will be tested eventually, no matter how hallowed its tradition. If experimental work and research conclusions in education are faulty, let us use our experiences and the resources of our respective fields of science to offer constructive suggestions for the improvement of experimental design and data analysis. If you have a contribution to make, get out of the armchair of your specific field of science and apply your methods to a wise analysis of what is needed in education. Keep in mind that free inquiry is as fundamental to progress in education as it is in all sciences and in these critical days we have little time or patience for the snobbish, haughty isolation of this privilege or with the cry that education does not lend itself to scientific inquiry.

Two simple aims. It is our purpose in this article, first, to begin in the reader's mind a clearer picture of American education than may be seen through the indignant protestations of individuals who feel

threatened by inquiry into assumptions they have always held dear. It is our hope in so doing that scientists may be persuaded to apply their talents and their authority to making constructive and discriminating contributions to education, whether they act as interested citizens, parents, school board members, research consultants, or in some other capacity.

Secondly, we wish to indicate that the attitudes and the methods, yes, and even the rigor of science are coming into education, directly and through the established social sciences. There is ample reason to hope that the fruits of this application, as it finds its initial slow way into teacher training and into schools, will be fully as great as those yielded by natural science. It is in this spirit that every true educator holds to the idea that "the proper study of mankind is man." It may be argued that teaching itself is an art. If so, it is an art which is raised to greater powers by knowledge, both for the rare persons who are intuitively successful in challenging students and for the great majority of teachers who acquire and increase their skills through practice and learning.

To particularize our latter aim, we will mention briefly two references which describe important experiments in learning. These *introductory* items can give all who are interested in improving education a sounder approach to its problems. The literature in the field is vast, and, as in any new focus of man's inquiry, it is sown with many tares as well as with wheat. However, any perceptive layman can read enough in a short time to permit his making intelligent criticisms and contributions to work in the schools. Where insufficient direct evidence yet exists, it is presumed that a factual description of the school situation as it is will afford each reader a framework within which to evaluate objectively both the criticisms of a philosophical nature and the remedies suggested by the critics to solve the educational problems before us.

Forces for change. The picture of education in this country depicts tremendous growth. For example, high school enrollment has about doubled itself every decade from 1890 to 1940! In terms of even greater significance to learning and teaching, the year 1890 saw 7 per cent of all eligible youth in high school, while 1950 finds 80 per cent of the eligibles actually enrolled. In comparison, no European nation ever put as many as 15 per cent of its eligibles into secondary schools of all types. The presence of more and more children in our secondary schools, with its great quantitative and qualitative impact on the grade schools below and on the colleges above, is not a question to be fruit-

fully argued by educators or by college professors. The children are there by public fiat—no sane philosophy of education can deny any of them a place. We must learn how each can find greatest profit in the schools.

This explosion in size in so short a period of time has naturally brought confusion, and at times chaos, in the attempts to adjust the activities of schools to the increasing public demands. And during this period, the scene was changing in many spectacular ways other than in the quantitative shifts in student enrollment.

Where did all these new pupils come from? From the large families of the flood of immigrants to this country during the late nineties and the early years of the twentieth century; from the city slums, as child labor became outlawed and compulsory education legislation swept the land; from the farms, as industrialization and urbanization grew and grew; from every corner of a booming nation they swept into the schools, bringing with them a diversity of cultural backgrounds and personal interests that overwhelmed the limited curricula then available.

At the same time, what was happening to the world about them as these youngsters embarked on a tour of classical study? Industry mushroomed and the products of technology offered an ever-changing wonderland of automobiles, trains, airplanes, radio, talking movies, and gadgets of every kind. The production of all these materials stimulated a concentration of peoples into urban centers, tearing the roots of a nation heretofore an agricultural empire. The emancipation of women added fuel to the fires which were consuming traditional family ties. Distances became as nothing, the kinds and amounts of job opportunities became legion, social and geographical mobility came to characterize the country. In the midst of this teeming, seething social context, youth witnessed staggering depressions, two world wars and the encroaching shadow of a third, the rise and fall of harsh and conflicting national concepts, the trends toward collectivism, concentration of government power, the rise of labor—no developments of youth, but certainly part of the world contributed to by the products of traditional schools. And in this raw, progressive environment, all of the sciences flourished and many new fields, such as psychology, genetics, biochemistry, biometry, cultural anthropology, and others, made impressive strides toward maturity, and provided the basis for a better understanding of both the aims and the methods of schools.

Strains in tradition. At first, the high schools

persisted in curricula which had been inherited or laid down for the privileged few who went on to college. It is extremely important to note that these curricula (in content, sequence, methods of handling, relatedness, and timing) were, and many still are, in no sense based on scientific evidence, or even on comparisons from trials and evaluations. Where they were not borrowed directly from tradition or from other nations, notably Germany, they were patched together largely by armchair logic. Further, they were originally constructed by specialist scholars who were concerned then with educating an elite few to become scholars in turn.

It was inevitable that such rigidity would fail, at least in terms of the humane problem resulting from the mass of students who could not and would not go to college or even finish high school. In 1940, in a publication of the American Youth Commission, *How Fare American Youth?* Lewis M. Terman estimates that an IQ of 110 is needed for success in traditional, classical high school curricula, and that 60 per cent of all American youth rank below this level.² This statement is supported by data in the same book which show, for example, that in a sampling of 30,000 Pennsylvania youth, only 42 per cent finished high school; in Maryland, 29 per cent graduated out of a sample of 13,538. In spite of these continuing high percentages of drop-outs from high school, greater numbers are reaching the colleges, which, in turn, find their students not all of the more "select" group of days not far gone. This spread of abilities with increasing population is little more than elementary statistics, but it leads a few unthinking professors directly to assume that the lower schools are degenerating, a cry most likely to be raised in, for example, a state college which cannot be as selective as some other institutions.

This kind of data, as well as local pressures placed upon the high schools by the specific needs of the community served, naturally and rightly led to a thorough questioning of classical curricula (and to investigation into learning itself) as the best experience either for the potential college student or for the much larger number of pupils for whom high school would be terminal. The old curricula and many methods allied with it were failing to work with great numbers of young people and, in many cases, continue to fail in the present. It is probable, but by no means proven, that many students reach college today who are poorer in the fundamentals of reading, writing, and arithmetic than their predecessors from the more select groups of the past. The former, struck with curricula not meant for them and quite foreign to their back-

grounds, often were *unable* to profit from much that their schools offered. Whether *mere* lack of proficiency in some of these usual standards (never end a sentence with a preposition) makes life in today's world less "successful" is simply another question for investigation and evidence, profane as this statement may appear to some. The inability of many children with high IQ's to learn in conventional school routines is well established by research. This is quite another matter than the "lowering of averages" due to new college populations mentioned in the paragraph above.

Educators are concerned now simply with finding the best methods of teaching and learning. Naturally enough, the question has been raised as to whether the elite and more intellectual few who were educated in times past succeeded largely *because* of their study routines or *in spite* of them. The latter question, of course, deeply disturbs many individuals who went through the more conventional schools; these feelings are perfectly understandable, but they do not invalidate the question.

In this connection, the careless use of terms like "modern education" and "traditional education" does much harm and tends often to activate the glands before it sets the brain in motion. Nothing is more certain than that all of us remember some instances of *good* teaching from the past and at all school levels, teaching that reached *us*, teaching that influenced our thoughts and behavior. In this sense, good teaching and learning are not a function of time in history. By "modern education," we mean here the discovery and promulgation, through research, of those practices which maximize learning (changes in behavior). Like all such definitions, ours is too simple, since it omits philosophies and policies having to do with the nature of ideal behavior; but it serves the immediate purpose. One would hope that in time all education will be modern; it has made greatest progress to date in the elementary schools.

By "traditional education," we mean those practices employed without reference to scientific observations from appropriate fields. The schools are still full of traditional work, despite our increasing knowledge about how people learn, about human behavior in general and the development of children in particular; colleges and secondary schools are the strongholds of traditional education. It should be noted that the above definitions form an observation about education of the past, but not a condemnation. Indeed, the schools of 1900 had no data with which to work; any teacher wishing to improve upon the usual formula of memorize-and-recite was on his own in uncharted seas.

Observation and experiment. We have suggested that it is fruitless and untrue to imply that in examining and questioning its methods education has discarded all that has been learned and all that is of value in the past. Rather, the attempt is being made, sincerely, if at times blunderingly, to find just what can be recognized as of value, out of past or present activities. If this attempt at recognition involves highly empirical experimentation, if it involves field testing of semiquantitative or even qualitative hypotheses, reflecting the newness of the field and the variability of the subject, this is no reason to dispute the search for truth. No evidence worthy of the title exists to prove that modern education has broken the intellectual and moral backbone of our youth, although claims to have witnessed this degradation are plentiful. On the contrary, sound evidence is slowly accumulating which points to the fact that not only are the youth in the school today learning the three Rs but they are learning them better than ever.

For those who would be better informed on the nature of this evidence, we would like to cite two studies, neither of which we shall attempt to reproduce here. The first of these, *An Evaluation of Modern Education*, published in 1942 by Leonard and Eurich,³ is a careful survey of a large number of research projects in grade and high schools, which had for their purpose (paraphrased):

1. To combat unjustified retrenchment in educational gains, *with data*.
2. To challenge the halo of traditional education, *with evidence*.
3. To remove the halo from some modern practices whose values may have been exaggerated, *with data*.

The authors then go on to say:

Clearly there is no educational panacea. A correct understanding of those practices that proved successful is a better source of material for the steady development of the educational program than unwarranted claims of mythical values.

Some of the more important conclusions of the research covered in this reference can be summarized as follows:

a) The products of modern schools are well disciplined in the basic skills. In practically every study and in almost every skill that has been investigated, students from the schools which follow the modern practices are slightly, if not markedly, superior to children from the more traditional schools. It is true, of course, that teachers using modern practices differ widely in their effectiveness just as do those following traditional patterns.

b) Modern-school students are well versed in knowledge and their use of it. These pupils have been shown to be superior to children working under the more usual forms of education. The same picture holds in regard to the ability to interpret facts and in the ability to generalize.

c) Products of the modern schools are successful at the higher educational levels.

d) The products of the newer schools have considerably higher ratings in physical fitness. The conventional schools are slightly, but not significantly, ahead of the newer programs in providing pupils with health information. The data on these particular matters are probably too meager to be relied upon with any degree of assurance.

e) It appears that graduates of the newer schools have better social-personal development for "effective citizenship." Studies show that modern schools are far and significantly more effective in developing self-initiative, critical ability, cooperativeness, civic beliefs, and leadership.

Now, sirs, if you do study in a book such as *An Evaluation of Modern Education*, take care that you read behind the convenient classification labels employed, such as "traditional" and "modern," and that you visualize the specific classroom practices which are being compared and evaluated in a given experiment. We have already tried to point out the futility and unreality in attempting to oppose the past with the present, as if one were all evil and the other pure virtue. Scientists who have ready to their hands the precise definitions of the natural disciplines must bear somewhat patiently with the jargon of a new field still struggling for the most useful units and concepts, to say nothing of the struggle for practitioners who know and can apply new knowledge.

Studies like the one above early proved that the traditional courses, each a separate part of a logical discipline (algebra, physics, etc.), were not necessarily the most efficient learning devices at all levels or for all pupils. The trial development of cross-discipline courses, the design of "core curricula," etc. are in no way refutations of the great heritage of man's ideas, ideals, and accomplishments. Most simply stated, these and other modern developments in education are attempts to devise better techniques for making such knowledge accessible and acceptable to others. Psychology and related studies have provided many new insights about how to reach students; this growing knowledge will be employed in time, in spite of nostalgia by the bucketfuls—it is a way with science, apparently. Its application in an experimental fashion in neither a real denunciation of teachers (who must always do what they can with their present wisdom) nor a fanatical new religion, although unknowing professors or educators can make it come out to be either. The poor experiment, the soapbox orator, these cannot be excuses to oppose professional education, any more than Lysenko and monkey-gland-quacks can give cause for the condemnation of genetics and medicine.

Emerging concepts about the personal "needs"

of students arose simply from observations and studies which showed how learning was improved whenever the student himself was considered as an important part of the learning process. In many classes, the teacher's actions still show the student to be conceived as an all-absorbing listener and memorizer instead of as a person with motivations, attitudes, interests, problems, hopes, and fears peculiar to himself. Not that the former view is in itself devastating to personalities—certain rare lecturers even thrill most of their students—but the latter orientation invites the use of facts which can better learning. All knowledge, no matter how it thrill the scholar, is claptrap if the student does not come to his own appreciation of it. The evidence indicates that in many traditional classes the majority of students are missing the understandings, the appreciations, the desires for new learnings we all seek to impart. The matter cannot and will not end here, not as long as anyone is interested in developing the talents of all children to their utmost.

And once committed to this task, educators find the road long and devious. In the way of best learning often stand physical, social, and emotional blocks; it were more accurate to state that the solution of common personal problems frequently makes itself that learning having highest priority.

Sally is currently an ugly teen-ager and has no friends; she is withdrawn and does nothing in classwork. Johnny's mother won't let him into the house until bedtime; he is unwanted at home and an aggressive brat in the traditional school. Bob's folks force him into college-preparatory work against his inclinations and capacities; he is sullen and unable to do any work. Henry and his changing body are all wrapped up at the moment in sex questions which have been held in mystery in his home. Jane is quiet, orderly, and gets "A" marks in all her work; yet her utter devotion to book-stuff somehow worries the teacher.

Extremes?—possibly; but what light they have thrown on the nature of all human learning! These and a myriad more in infinite variety are commonplaces in every school today. Only laymen argue endlessly about which duties "belong" to schools, which to churches, which to the family, etc. A good public school teacher cares not for such games, for there his pupils sit, *real persons*, not intellects only—none of their problems are left at home. Educators have no interest, only antipathy, for "usurping" the family as a primary place of child-training. The fact is that they are confronted with human beings in the classroom who are there to learn those things which will lead to more learning, and whatever facilitates this process is a part of the business. Because of their pungent experiences, educators may be led to argue as to the meaning of

undeniable changes in the family, but this has nothing to do with their job on Monday or Thursday.

High school to college. The second reference is *The Story of the Eight Year Study* by W. M. Aikin, which is a summary of a five volume report.⁴ In this study, thirty high schools were released from all standard college entrance requirements, beginning with the 1936 college class, for a period to cover four graduating classes. This was done with the consent and approval of colleges throughout the United States. Each high school was free to design its own program for college preparation. The evaluation of the study depended upon success in college, in part through the use of 1,475 matched pairs of students, each pair representing one of the experimental schools and one school employing a traditional curriculum. The complexity and significance of this study can only be appreciated by reading the report.

However, the results are summarized by the following quotation from a report to The Association of American Colleges by Herbert C. Hawkes, dean of Columbia College, on January 10, 1940:

In order to obtain a comparison between the Thirty Schools graduates and their mates in the control group, members of the staff of the Eight-Year Study have visited the institutions where any considerable number of the students were registered in order to become personally acquainted with them and with their controls, so that they might reach as well considered opinions as possible regarding their adjustment to the work of the college, and the measure of success that they attained, both in their studies and in their social relations. Comparisons in each of the major fields of study between the Thirty Schools graduates and their control mates have been made with scrupulous care. I will not go into the statistical results at this time. Sufficient to say that a comparison of the 1,475 students from the Thirty Schools, which were about evenly divided between the sexes, indicates very little difference in college grades between them and their controls. On the whole, the students from the Thirty Schools were superior to the control group. Those who have been in college for three years excelled slightly in the humanities, the social sciences, and the physical sciences. The grades were almost exactly even in English and the biological sciences. They were distinctly inferior in the foreign languages, but distinctly superior in such subjects as fine arts, music and the like. I will not attempt to analyze the results for those who have had only two or one year of college experience, except to say that the students from the Thirty Schools who entered in 1938, and whose college records for only one year are available, excel their controls from the other type of school in every field of study, notably in English, humanities, physical sciences, and mathematics. This may reflect the careful job that the faculties of the Thirty Schools have done during the past three years in improving their curriculum, and affording a more adequate intellectual training for their students.

One further observation is interesting. A report on the college success of the graduates of the six of the Thirty

Schools whose programs differ most from the conventional pattern is compared with that of their comparison groups. A complementary report has been made on the college success of the graduates of the six of the Thirty Schools which differ least from the conventional pattern as compared with their matched pairs. There were 361 students from the least conventional six schools, and 417 from the most conventional schools. It turns out that the students from the least conventional schools excelled their controls by a score that may roughly be expressed as 27 to 7, while the students from the most conventional schools of the Thirty were excelled by their control group by a score that may roughly be expressed as 14 to 16. That is, so far as these data are significant, the students from the schools whose pattern of program differed most from the conventional were very distinctly superior to those from the more conventional type of school.

I should add that in extra curricula interests non-athletic in character, the graduates of the Thirty Schools were markedly more alert than their comparison group.

The results of this Study seem to indicate that the pattern of preparatory school program which concentrates on a preparation for a fixed set of entrance examinations is not the only satisfactory means of fitting a boy or girl for making the most out of the college experience. It looks as if the stimulus and the initiative which the less conventional approach to secondary school education affords sends on to college better human material than we have obtained in the past.

I may add that this report to you has been approved by a Committee of the Commission on School and College Relations consisting of the following membership: President Barrows of Lawrence College, President Park of Bryn Mawr, Dr. Gummere of Harvard, Dean Speight of Swarthmore, Dean Brumbaugh of Chicago, and myself.

It is of interest to note that the methods of statistical analysis used in the Eight Year Study have been attacked. One such critique recently appeared in *School and Society* (Nov. 25, 1950). Again, we leave the judgment of both the research and its weaknesses in your hands. The significant point to be made here is that this is sincere, intelligent, honest research, of a type that will eventually supply a rational rather than an emotional basis for curricula design.

Opportunity unlimited. Here then is a problem of some complexity. The public has committed itself as a nation to "mass" education, which research has found to mean a great and unyielding spread of talent at all levels of the educational system. At the age level of five years, 96 per cent of the children in a representative sample may be grouped to exhibit a range of general ability equivalent to a four-year spread in ages—some will be as "smart" as an average child of seven, while others can do no better than a three-year-old. The remaining 4 per cent of the age-five children will show even more extreme differences in ability! By the time these children are eleven, 96 per cent of them will show an ability span equivalent to eight years of age. Further, any one child's range of aptitudes and interests will cover 80 per cent of the differences

exhibited in his age group. These powerful and creative differences in individuals are *increased* by effective teaching, i.e., by all forms of teaching which significantly take into account the individual's capacities and interests as well as those of the teacher. Only rote learning, straight memorization, can reduce these differences as between persons.

Facts such as those cited here are bringing down the curtain on much of traditional education, because it was founded in large part on the notion that all students should be brought to a common level of attainment in all areas. Investigation has made it evident that such a goal is as boring to those of superior abilities as it is frustrating to those below the mark. Thus, waste and mischief receive common invitations.

No one truth, no one brand of scholarship can be adapted to all. The variability in capacity, opportunity, cultural background, local interests, health, parental influence, and other factors, staggers the imagination. Yet at once we are faced with a profound challenge which demands our utmost cooperation in designing a flexible, intelligent, experimental approach to school programs.

But the schools cannot pause while we experiment and deliberate. The rapid rise in school populations has outstripped most school systems, hobbling effective organization and excluding almost all problems except those technical considerations on sheer numbers and adequate space. On the other hand, research is always slow to find its way into the schools, which are public domain. Even practices or equipment of unquestionable worth are difficult to take across community lines, for education is public policy as much as it is art or science.

And the publics are many. There are almost 100,000 school districts in the United States, all practically autonomous, largely controlled by non-professional people, who are either elected, appointed by an elected commission or a commission appointed by the state governor, or appointed directly by the governor. There is here created as heterogeneous a policy toward educational administration as could be conceived. In fifteen states, a school superintendent is not required to have a college degree; in nine states neither a degree nor any courses in professional education are required as prerequisite to appointment. In 1948, there remained over 75,000 one-room schools. In eighteen states, over one half of all grade schools were of the one-room type, ranging in percentage up to 96.8

per cent for Iowa. In 1948, 16.8 per cent of all high schools contained less than fifty pupils; 58.8 per cent of all high schools had less than 100 students. Only six states had more than half the high school students in schools of more than 100.⁵

The public, furthermore, does not yet see fit to appropriate enough money to pay for better persons as educators nor to pay for better training of teachers. The estimated average salary in 1950-51 of all instructional personnel in the public schools is \$3,080 (or about \$1,772 in prewar dollars) which is less than average earnings in industry. Results: 40.9 per cent of all grade school teachers have no college degree; 3.2 per cent are without any college training, and in five states over 10 per cent of all grade school teachers were without college preparation (up to 32.2 per cent in North Dakota). Does this argue for certification and the establishment of minimum standards for teachers? The finance question alone is exceedingly complex, and cannot be discussed here. But, against those who shout about expensive new fads and frills, one fact should give pause to intelligent persons: In 1937-38, this country spent 3.1 per cent of its income on public education—in 1948-49 the figure had fallen to 2.3 per cent. *Caveat emptor!*

Be up, not down. But there is no end to the painting of this picture. One can only hope that enough of the outline has been drawn to help in raising scorn to personal concern, to imbue concern with thoughtfulness, and to spur thought into active aid.

We have tried to point out that educators, operating within the complex picture sketched above, have but *one* basic assumption: Teaching and learning are subject to inquiry and experiment, as are all fields of thought and endeavor. Scientists in particular should find it difficult to quarrel with such a beginning. Our special plea has been that all persons heed the quote used by Fuller (so amusing in that place), "People who are not up on a thing are usually down on it." Don't let it happen to you!

References

1. RICHARDS, I. A. *How to Read a Page*. New York: Norton (1942).
2. RAINY, H. P. *How Fare American Youth?* New York: D. Appleton-Century (1940).
3. LEONARD, J. P., and EURICH, A. C. (Eds.) *An Evaluation of Modern Education*. New York: D. Appleton-Century (1932).
4. AIKEN, W. M. *The Story of the Eight Year Study*. New York: Harper (1942).
5. *The Forty Eight State School Systems*. Chicago: Council of State Governments (1949).

On the Number of Species of Plants

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IT IS a well-known fact that the past fifty years have seen great advances in the science of botany, and it is generally recognized that taxonomy has shared in, and contributed in no small way to, this achievement. Not only are taxonomic principles better understood and systems of classification more clearly elucidated, but it is a rather remarkable fact that the number of species of plants known to science has been nearly doubled during the first half of the present century, and publication of newly discovered and described species continues at the rate of several thousand each year. Although criteria of species are not absolutely equal for all botanists, the consequence of this difference is insignificant in consideration of the immense number of species, and it is of scientific interest to attempt to ascertain how many species of plants are known at the present time.

The question of number of species, genera, and families of plants has more than a statistical significance. It is closely connected not only with taxonomy, but also with plant geography and ecology, which are usually concerned with numerical relations of plant species. The problems of plant systematics, together with the important evolutionary theories of more general biological scope, are inseparably connected with consideration of the rate or tempo of formational processes and morphological diversity already achieved in the plant world. Practical selective work with cultivated plants often requires, ultimately, a fundamental knowledge of the species and forms of wild plants, both those of already well-known economic importance and those newly discovered and described.

Historically, the discovery, recognition, and de-

scription of "new species" of plants have been slow and laborious. This has been carried on for several centuries by hundreds of botanists in many lands. The painstaking work of these scientists has not always been adequately rewarded, or even recognized. As Linnaeus (1737) said:

What toils, what science would be more wearisome and painful than Botany, did not some singular spell of desire, which I myself cannot define, often hurry us into this pursuit, so that the love of plants often overcomes our self-love? Good God! When I observe the fate of Botanists, upon my word I doubt whether to call them sane or mad in their devotion to plants. . . . Alas that so much toil should win so slight a reward; and yet how welcome such a reward would be!

Nor are the recognition and appreciation of the work of the discoverers of species always marked with enthusiasm. Liberty Hyde Bailey (1947) comments:

One of the strangest quirks of the human mind is opposition to the founding of species. I do not know why this conceitedly senseless antagonism ever came into being. One would suppose that men would be glad to have all the entities on the planet recognized and named; such procedure should add greatly to interest in living. We accept other findings in science with ardor, even very technical discoveries that others can never verify or even comprehend; yet the taxonomist who pursues his investigation with equal honesty and conviction is met with indifference or even objection. In fact, the systematist is likely to be called either a "lumper" or a "splitter," two self-confident and disgraceful words that should never have come into the language in relation to work of the taxonomist; they mean nothing except to expose the prejudices of the objector, more vehement when the objector knows little or nothing about the group in question. It is supposed that one of the graces derived from the study of science is to withhold judgment until there is reason for statement.

In view of the importance of this subject, it is

not surprising, therefore, that even in the eighteenth century the number of species of plants was already under scientific investigation, although two thousand years earlier a beginning had been made by the Greeks. Table 1 summarizes the development of our knowledge of the number of known species of plants.

Synopsis of Calculations of Number of Species

Theophrastus (370-285 B. C.), perhaps the first real botanist, knew only about 500 kinds of plants (Hort, 1916), and for nearly two thousand years little was added to the scientific understanding of even the common plants of Europe. In 1753, Linnaeus knew only 5,950 species of all kinds of plants in the entire world. In 1807 Persoon recognized 20,000 species of flowering plants. By 1819 De Candolle could account for 30,000 species. A short time later, Steudel (1821, 1824) enumerated 70,000 species of all plants. One hundred years after the publication of Linnaeus' *Species Plantarum*, Lindley (1853) was able to place the estimated number of known genera and species "as far as was known in 1845," at 8,935 genera and 92,930 species. In 1877 Duchartre estimated the number of known plants of all groups at 125,000. In 1888, Th. Durand listed 100,220 species of phanerogams.

At the beginning of the present century S. H. Vines, following Saccardo's compilations closely, estimated the total number of known species to be 175,596, of which 105,231 are angiosperms and

gymnosperms. In 1910 J. C. T. Uphof listed by genera all plants we now include in the phylum Tracheophyta—namely, pteridophytes, gymnosperms, and angiosperms, with a total of 295 families, 9,084 genera, and 137,603 species.

There are two practical methods for determining the number of species already known and described. First, there is the empirical method of counting all the binomials in standard indices, and, second, the method of extrapolation based on certain principles of nearly constant ratios among different groups of plants. The first, and probably more precise method, although most laborious, and limited, of course, to phanerogams only, is the direct count of all binomials listed in *Index Kewensis*. Since this great work is an index, not a nomenclator, the count must not be made mechanically by averaging the number of names in each column, but should be made critically, excluding synonyms, as well as most binomials in those genera (*Hieracium*, *Taraxacum*, *Rubus*, etc.) known to be partly or facultatively apomictic. Corrections should be made by comparing lists of names in *Index Kewensis* with recent critical monographs. Evidently this method will not give us the exact number of known species, but it will give an idea of the rates of increase in numbers and will also disclose the number of monotypic genera and families.

The second method is based on the principles of Robert Brown and A. von Humboldt that there exists a constant numerical ratio among the larger

TABLE 1
DEVELOPMENT OF KNOWLEDGE OF SPECIES OF PLANTS

		All Plants	Only Spermatophyta	All Tracheophyta	Hypothetical Total Existing Species of Plants
Theophrastus	300 B. C.	500	.....	.....	.....
Linnaeus	A. D. 1753	5,950	.....	.....	.....
Persoon	1807	.....	20,000	.....	.....
Willdenow	1808	.....	14,457	.....	.....
Brown, Robert	1814	37,000	.....	.....	.....
Humboldt	1817	.....	38,000	.....	426,000
De Candolle	1819	.....	30,000	.....	.....
Steudel	1824	70,000	.....	.....	.....
Lindley	1853	92,930	79,440	.....	.....
Duchartre	1877	125,000	.....	.....	.....
Durand	1888	.....	100,220	.....	.....
Saccardo	1892	174,000	105,231	108,615	400,000
Vines	1900	175,596	105,231	.....	.....
Uphof	1910	.....	.....	127,603	.....
Bessey	1910	210,000	110,000	114,000	.....
Engler and Diels	1936	.....	165,597	.....	.....
Jones, G. N.	1941	335,000	195,000	205,000	.....
Smirnov	1943	.....	250,000	.....	500,000
Merrill	1943	335,000	.....	.....	.....

groups of the plant kingdom. For example, *Compositae* contains 10 per cent of the species of dicotyledons; monocotyledons constitute slightly more than 20 per cent of all angiosperms; and *Orchidaceae* includes about 40 per cent of monocotyledons. Hemsley (1888) presents some interesting tables showing the relative position of a large number of families (and genera) in the floras of the world. Although these statistics are now more than sixty years old, it is instructive to observe that in general the relative positions of the families ("orders," according to botanists of that period) remain essentially the same today, despite the fact that the total number of known species has more than doubled. Sir J. D. Hooker (1888) comments: "The conditions which have resulted in monocotyledons retaining their numerical position, of one to four or thereabouts of dicotyledons in the globe and in all large areas thereof are, in the present state of science, inscrutable." According to this theory, the relative size of families does not change radically with increase in our knowledge of the species, because relatively larger numbers of new species are discovered in the large families than in the small ones, and the comparative differences remain essentially the same. Having determined the average percentage of rate of numerical increase in a selected group of families, we can take this figure as the theoretical probable average for the other families. We can apply this coefficient to the remaining groups, and thus obtain a reasonably dependable figure for the total number of all species of plants known at the present time.

Employing the first method and summarizing the previous twenty-five years (1910-35) of systematic botany, E. D. Merrill (1936) estimates the annual accretions in our time of newly described species in all groups of plants to equal or exceed the total number of species known to Linnaeus in 1753.

The tremendous developments of the past hundred and fifty years in our knowledge of the world's vegetation, the wealth of reference material available in the public and private herbaria in leading countries, the vast and complicated literature of world botany, all testify to the inexhaustible vitality of this, the oldest branch of botanical science. Thus in the field of systematic botany covering the higher groups of plants, from 1910 to 1935, as noted above, nearly 120,000 new species of plants have been described, averaging at least 4,800 per year.

Following the second method, the writer (Jones, 1941) attempted to supply a summary of the known species of plants to the end of 1940, at which time it was estimated that the total number was about 335,000. This intentionally conservative estimate is, however, now in need of revision, es-

especially because the figures for the true fungi (Eumycophyta), compiled from Saccardo (1892) and Engler and Diels (1936), were in all probability too high. In the present revision, the computations of Bisby and Ainsworth (1943) have been accepted instead. The principal consequence of this change is that in the present discussion the number of fungi is reduced to conform with the latest critical estimates, and the numbers of gymnosperms and angiosperms are revised upward, as is required by the steady rate of discovery and description of new species in these groups.

In 1943, E. D. Merrill, referring again to this subject, said:

As various parts of the world were opened up within the few centuries following the expansion of the European colonizing nations the number of species utilized rapidly increased; and this tempo of increase continues unabated. Within the present century about 265,000 new binomials have been published for the flowering plants and vascular cryptogams alone, of which about 194,000 represent hopefully proposed new species, the remainder shuffles or transfers from one generic name to another. The yearly average for the higher groups alone is now approximately 6,500 as *new binomials*, of which about 4,750 represent proposed new species. This is the record of the twentieth century to date. As to the total number of distinct and more or less "known" species, who shall say? [G. N.] Jones has briefly discussed this matter calling attention to the remarkable discrepancies that occur in recent texts, with a spread in the estimates of from 133,000 (Uphof's estimate of 1910) to 175,000 for the angiosperms alone; and concludes that the total for all known groups is in the neighborhood of 335,000. Because of various complications that it is unnecessary to discuss here, I suppose that we may conclude that one guess is as good as another; but knowing something about synonymy; something about the limiting factors in the geographic distribution of individual species; something about more or less universally distributed species; something about the extraordinary richness of tropical floras; something about the remarkable local endemism in various tropical areas; something about the high percentage of novelties that are found in all new collections from hitherto inadequately explored areas; something about those regions that, within the past four decades, have been particularly rich in the crop of new species—my guess is pretty close to that of Jones, and that the total number of reasonably valid described species in all groups is well in excess of 300,000. Even if the number of valid species should be only half this total, what scientist, no matter what his field, would even have the temerity to suggest that we can get along without taxonomy and nomenclature?

In 1943 a Russian article by A. L. Smirnov on the number of species of plants attempts to correct some overconservative estimates made by previous authors. Following the method of extrapolation, Smirnov found that the number of known species in 136 selected families increased in a few decades from 66,000 to 115,000, or an increase of 74 per

cent. Assuming the same rate of increase to have occurred in the remaining families of angiosperms, he arrives at the conclusion that the number of known species of phanerogams is now about 250,000, and that it is safe to assume that ultimately we shall discover close to half a million.

In 1948 Hutchinson concluded that there are at least 14,000 genera of flowering plants in about 340 families. This is almost twice the number recognized in the latter half of the nineteenth century by Bentham and Hooker, who treated 7,585 genera of angiosperms (A. Gray, 1883) in their *Genera Plantarum*. J. C. Willis (1940) records that 4,853 of the 12,571 accepted genera of all vascular plants (up to 1915) are monotypic, or nearly 40 per cent. A similar conclusion is drawn by Bisby and Ainsworth concerning fungi—namely, that nearly half the known genera are monotypic.

Species of Fungi

Saccardo's estimates (1892) for the fungi, and predictions of numbers of species yet to be discovered, were probably rather high. As pointed out by Bisby and Ainsworth (1943), Saccardo's main task in the *Sylloge Fungorum* had to be the compilation of new descriptions—addition not subtraction. "The figure for Myxomycetes is about double the correct number; that for *Fusarium* (over 500) nearly ten times the number now accepted, and so on." These authors present a table of the number of genera and species of fungi up to 1940, giving a grand total of approximately 37,500 species in 3,500 genera, but they conclude that for several reasons this number of species is too large, and that "there are about 34,000 species now known, of which no more than 25,000 are based on morphology." They conclude that probably about one third of the existing species of fungi have been described to date, and that there may be altogether as many as 100,000 species, because tropical and most other areas when thoroughly explored by mycologists will yield thousands of previously unknown fungi.

Two years later these authors say that

there are 7,405 generic names, 3,705 "good" (1,765 monotypic)+3,700 syn., or uncertain, with some 38,000 sp., and it is probable that there are at least 100,000 species of Eumycetes present on the Earth. It is true that there are even now some 100,000 specific names, but less than 40,000 are taken as "good," and a great number of these are based on morphology + host. The number is still smaller if fungi having named perfect and imperfect forms are taken into account. There are some 200,000 "good" species of Phanerogams. The number of individual fungi is very great. For example, in 1 gm. of soil there may be 100,000 or more living fungus spores or bits of mycelium, and an even greater number of bacteria. Al-

most all organic materials in nature are broken down by different fungi; almost every higher plant may be attacked by fungus parasites.

Another comment on the numbers of fungi is made by Martin (1941) as follows:

It is difficult to estimate, with any assurance, the total number of species of fungi. One obvious reason for this is the fact that many fungi are extremely inconspicuous and are very likely to escape observation unless special search is made for them. This is particularly true of the forms which, unlike the plant pathogens and similar groups, are not of immediate concern to some human interest. Another reason is the difficulty of formulating a species concept as applied to fungi comparable with that used in the study of other groups, notably the vascular plants. In the twenty-five volumes of Saccardo's *SYLLOGE FUNGORUM*, the latest of which appeared in 1931, over 89,000 species are listed. Some of these have been shown to include two or more related but distinct species and the number would be correspondingly increased. A larger number have been shown to be synonyms, thus decreasing the total. One suggestive approach is a comparison of parasitic fungi and host plants. For several years the class in mycology at the University of Iowa has been asked to tabulate the number of parasitic fungi listed in Seymour's *HOST INDEX* as occurring on vascular plants selected from Gray's *MANUAL* by an arbitrary system of sampling designed to eliminate any selective factor. The result, when the sample is sufficiently large, has uniformly been a number of host species of fungi varying from approximately the number of species to several times that number. When the host sample is restricted to a large family, such as the *Compositae*, the number of species of fungi is relatively low, due to duplication, as might be expected. The vascular flora of Iowa may be regarded as well known, and the fungi as relatively so. Gilman and Archer (*Iowa State Coll. Jour. Sci.* 3: 299-502, 1929) and Gilman (ib. 6: 357-365, 1932) list 995 species of fungi occurring on 1035 host species, of which 1008 are vascular plants, almost exactly five-eighths of the vascular species occurring in Iowa. There is no reason to suppose that the remaining three-eighths are free from parasites. When to these are added the very large number of fungi occurring in soil and on organic debris of every sort it is not unreasonable to postulate that the number of species of fungi in this area is not less than the number of species of vascular plants and to hazard the suggestion that such relation may hold for much of the land area of the world.

Table 2 shows the approximate numbers of known species and genera of all plants up to 1950. The classification is that of Tippo (1941, 1942). A notable feature is the disparity shown between the number of species included in the different major groups. By way of general explanation it would seem probable that the smaller groups reached their numerical peak in past geological periods, whereas at the present time the flora of the world is characterized by the preponderating angiosperms and fungi.

Toward the end of the nineteenth century about 100,000 species of living seed-plants were known.

TABLE 2

APPROXIMATE NUMBERS OF KNOWN SPECIES AND GENERA OF ALL LIVING PLANTS

Major Groups	Species	Genera
Subkingdom "Thallophyta"		
Phylum Cyanophyta (blue-green algae)	2,500	150
Phylum Euglenophyta (euglenoid algae)	335	25
Phylum Chlorophyta (green algae)	5,700	360
Phylum Chrysophyta (yellow-green algae, diatoms)	5,700	300
Phylum Pyrrophyta (cryptomonads, dinoflagellates, etc.)	1,000	135
Phylum Phaeophyta (brown algae)	900	190
Phylum Rhodophyta (red algae)	2,500	400
Phylum Schizomycophyta (bacteria)	1,335	122
Phylum Myxomycophyta (slime fungi)	450	63
Phylum Eumycophyta (true fungi)	40,000	3,585
Subkingdom "Embryophyta"		
Phylum Bryophyta (bryophytes)		
Class Musci (true mosses)	14,000	660
Class Hepaticae (liverworts)	8,500	175
Class Anthocerotae (hornworts)	320	5
Phylum Tracheophyta (vascular plants)		
Subphylum Psilopsida (psilopsids)		
Class Psilotineae		
Order Psilotales	4	2
Subphylum Lycopsida (lycopsids)		
Class Lycopodineae		
Order Lycopodiales (club mosses)	180	2
Order Selaginellales	700	1
Order Isoetales (quillworts)	64	1
Subphylum Sphenopsida (sphenopsids)		
Class Equisetinae		
Order Equisetales (horse-tails)	25	1
Subphylum Pteropsida (pteropsids)		
Class Filicinae (ferns)		
Order Ophioglossales	90	4
Order Marattiales	190	6
Order Filicales	9,000	250
Class Gymnospermae (gymnosperms)		
Order Cycadales (cycads)	100	9
Order Ginkgoales (gingko)	1	1
Order Coniferales (conifers)	550	50
Order Gnetales	71	3
Class Angiospermae (flowering plants)		
Subclass Dicotyledoneae	200,000	9,500
Subclass Monocotyledoneae	50,000	3,000
Total	344,215	19,000

Taking the extremely conservative rate of discovery as only 3,000 "good" species per annum (about three fifths of Merrill's estimate), at the very least there have been 155,000 new species discovered during the past fifty years. This brings us the estimate of 250,000 known species of seed-plants at the middle of the twentieth century. This conclusion is supported by compilations from a number of modern taxonomic monographs and revisions, as well as from the sixth edition of Willis' *Dictionary* (1931), and Engler and Diels' *Syllabus* (1936). That this computation is probably not excessive is suggested by the fact that in the twenty largest families of dicotyledons there are more than 100,000 known species. In monocotyledons more than half the known species belong to two families, Orchidaceae and Gramineae. Similar estimates for all seed-plants have been reached independently by Smirnov (1943), and Turrill (1949).

The figures for algae and bryophytes are from G. M. Smith (1938), but according to Francis Drouet, curator of cryptogamic botany, Chicago Natural History Museum, the numbers of blue-green algae as commonly given in textbooks are much too high. Thousands of names must be withdrawn as synonymous, etc. Too many new species have been described because the plants collected did not look like the published drawings. The number of valid species will be substantially reduced, as many so-called species are no more than growth-forms and not taxonomically recognizable entities. The modern estimates for fungi are from Ainsworth and Bisby (1945), and those for gymnosperms from Buchholz (1946), with a few additions during the past five years. Th. Just expresses the opinion, based on his current studies of cycads, that this group should be scaled down to 80 or fewer species. The data for species included in the subphyla Psilopsida, Lycopsida, and Sphenopsida are according to Engler and Diels (1936), and for Filicinae, Christensen (1938), and Copeland (1947). Thus, the approximate number of more or less known species in the larger groups of plants may be estimated as algae, 17,235; fungi, 40,000; bryophytes, 23,000; ferns, 9,000; gymnosperms, 722; and angiosperms, 250,000; and the total number of all species of living plants known in the middle of the twentieth century is seen to be nearly 345,000.

Even so, it appears probable that we have not yet made the acquaintance of half the existing species of plants. After more than two centuries of progress, descriptive systematic botany can be said to have scarcely made much more than a good beginning. We are still in the exploratory stage. Every

botanical expedition brings back quantities of specimens of newly discovered species. For example, Julian Steyermark, of the Chicago Natural History Museum, tells me that of 8,102 collections he made in Venezuela, 550, or nearly 7 per cent, turned out to be new species. In an area in the state of Tachira 165 of the species collected are "new." On a trip to Mount Duida, out of 800 collected, nearly 100 are new species.

Although Mount Roraima has been explored since the days of Schomburgk, slightly over 100 years ago, my collections from that area yielded a 5% turnout of new species. In Ptari-tepui 15% of the flora proved to be new to science. In some parts of this region even higher concentrations of new species were found. For example, Carraotepui (a spur of Ptari-tepui) yielded 25% new species, the mesa at the base of Ptari-tepui in the region of Santa Teresita de Kavanayen yielded 29% new species, an area on the slopes of Ptari-tepui yielded 30% new species, while three collections taken from a small stream yielded 100% new species.

It should be emphasized that the high proportion of new species discovered is by no means the result of one taxonomist's "fine splitting," but that it represents conclusions reached by leading authorities of various plant families, combined with Dr. Steyermark's own general studies outside those particular families. That these are well-marked distinct species is borne out by the judgment of specialists who have devoted all their time to the study of those particular families, and who, by virtue of

devotion and critical attention to the plants they study, merit the greatest respect of other taxonomists and scientists in general. It should be mentioned, of course, that the greatest number of new species was from previously botanically unexplored or slightly explored regions. Practically all new species encountered are endemic to those particular places where they were collected. "It would be no exaggeration to state," says Steyermark, "in view of my own experiences in Venezuela and other countries, such as Guatemala and Ecuador, that the numbers of new species of vascular plants, not to mention the cryptogams, yet to be discovered in the New World tropics will be legion."

That these conditions are not confined to tropical regions and that similar opportunities for critical taxonomic discoveries exist in the United States, as well as other relatively well-botanized regions, is shown by the following excerpt from a study of lichens.

To summarize the contributions to the knowledge of Lecidea resulting from this study, 88 species are reported, approximately tripling the number to be reasonably ascribed to the Adirondack mountain area from existing reports. Of these 88 species 5 new species and one new variety have already been described by Dr. A. H. Magnusson from these collections, and 15 additional species are described as new in this paper; 16 species are reported for the first time from North America; 8 species represent marked extensions of the known range, and 5 species are reduced to synonymy (Lowe, 1939).

Bibliography

AINSWORTH, G. C., and BISBY, G. R. *A Dictionary of the Fungi*. (2nd ed.) Kew, Eng.: Imperial Mycological Institute (1945).

BAILEY, L. H. *Gentes Herbarum*, 7, 194 (1947).

BESSEY, C. E. *Science*, 32, 669 (1910).

BISBY, G. R., and AINSWORTH, G. C. *Trans. Brit. Mycol. Soc.*, 26, 16 (1943).

BREED, R. S., MURRAY, E. G. D., and HITCHENS, A. P. *Bergey's Manual of Determinative Bacteriology*. (6th ed.) Baltimore: Williams & Wilkins (1948).

BROWN, R. *General Remarks, Geographical and Systematical on the Botany of Terra Australia*. London (1814).

BUCHHOLZ, J. T. "Gymnosperms," in *Encyclopaedia Britannica*.

CHRISTENSEN, C. In F. Verdoorn (Ed.), *Manual of Pteridology*. The Hague, 522 (1938).

COPELAND, E. B. *Genera Filicum*. Waltham, Mass.: Chronica Botanica (1947).

DE CANDOLLE, A. P. *Théorie Élémentaire de la Botanique*. (2nd ed.) Paris (1819).

DUCHARTRE, P. E. *Elements de Botanique*. (2nd ed.) Paris (1877).

DURAND, TH. *Index Generum Phanerogamarum*. London (1888). Review by J. Britten, in *J. Botany, Brit. and For.*, 26, 316 (1888).

ENGLER, A., and DIELS, L. *Syllabus der Pflanzenfamilien*. (11th ed.) Berlin (1936).

FULLER, H. J. *The Plant World*. New York: Holt (1941).

FULLER, H. J., and TIPPO, O. *College Botany*. New York: Holt (1949).

GRAY, A. *Am. J. Sci.*, 126, 245 (1883).

GREENE, E. L. *Landmarks of Botanical History. Smithsonian Inst. Pubs. Contribs. to Knowledge. Misc. Collections*, 54, 1-329 (1909).

HEMSLEY, W. B. *Biologia Centrali-americana*, Vol. I. London (1888).

HILL, J. B., OVERHOLTS, L. O., and POPP, H. W. *Botany, a Textbook for Colleges*. (2nd ed.) New York: McGraw-Hill (1950).

HOOKER, J. D. In W. B. Hemsley, *Biologia Centrali-americana*, Vol. I, lxiii (1888).

HORT, SIR ARTHUR, Trans. of Theophrastus' *Enquiry into Plants*. London: Putnam's Sons (1916).

—. *Linnaeus' Critica Botanica*. London: Ray Society (1938).

HUTCHINSON, J. *British Flowering Plants*. London: Grawthorn (1948).

JONES, G. N. *Science*, 94, 234 (1941).

KNOWLTON, F. H. *Plant World*, 2, 65 (1899).

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Mineral Resources and International Understanding

KIRTLEY F. MATHER and HOWARD A. MEYERHOFF

The authors of this article have much in common. Both are officers of the AAAS, both taught for many years in Massachusetts institutions of learning, and both have wandered off the beaten track in search of geologic facts. Their concern about international interdependence seems to have had its origin in expeditions to Latin America, designed to locate mineral reserves that might be utilized to the mutual benefit of the countries south of the border and of the United States.

ALMOST every application of science through technology to human affairs involves new or increased demands upon the mineral resources stored within the earth. Mechanization of industry, commerce, and agriculture inevitably leads to an increase in per capita consumption of metals, nonmetallic minerals, and mineral fuels. Man has extracted and used a greater quantity of mineral resources during the past half century than throughout all the preceding millennia of human history. We may confidently expect that even greater demands will arise during the second half of the twentieth century—unless “civilization” destroys itself—as the benefits of science are acquired in greater measure by the large fraction of humanity not now enjoying them to any significant degree. The influence of mineral resources upon international relations has already been profound, and it will become more rather than less notable during the next few generations.

Every Nation Dependent on Every Other

Basic to any consideration of the potentialities of that influence is the fact that mineral resources are not renewable. They are in the category of nature's stored capital, not of man's annual income. Although the geological processes responsible for their presence continue to operate today as they did during ancient geological time, the rate at which those processes produce results is so slow that it has required hundreds of thousands of years to provide the resources that man now uses in a single year. For all practical purposes the earth must be considered as a storehouse of mineral resources, not as a factory. The stores of certain substances are so

abundant that all human requirements may easily be met for many thousands of years in the future, but others are present in such short supply that they will be exhausted within a few centuries, and substitute materials, or alternative sources of the same materials, will have to be found.

Equally relevant is the fact that many of the most important mineral resources are available in only a relatively few places, widely scattered over the earth's surface. It was the high-grade iron ore of Minnesota, the English Midlands, and Lorraine, combined with the readily accessible coal of Pennsylvania, Wales, and the Ruhr that enabled the United States, Great Britain, and Germany to attain outstanding leadership as industrialized nations during the last half of the nineteenth century. At the present time the demands of industry for mineral resources have become so diversified that materials must be brought to manufacturing centers from hundreds of different types of mineral deposits, many of them in remote parts of the earth. No nation, with the possible exception of the Soviet Union, covers a sufficient variety of geological structures to permit its citizens to secure from domestic sources adequate supplies of all the minerals required for industrial maturity in this age of science and technology. Mineral interdependence among the nations of our well-stocked earth is one of the most significant facts of life at this midpoint of the twentieth century.

Today the United States is inescapably dependent upon foreign sources for the ores of nickel, tin, cobalt, and uranium. Our domestic sources of antimony, chromium, manganese, mercury, tungsten, and platinum are woefully inadequate to meet our

needs. We are the largest consumer among the nations of the world for almost every item on the long list of mineral resources, but we are at the bottom of the list of nations arranged in order of production of certain of those items, and far below the top for many others. Stockpiling of certain mineral supplies to be ready for a possible emergency is an obvious necessity under present conditions and drives home the fact that we are not, and cannot be, a self-sufficient nation.

From a strictly geological viewpoint, it is now evident that the earth is far better adapted for occupation by men organized on a world-wide scale, with maximum opportunity for free exchange of raw materials and finished products, than it is for occupation by men who insist upon building barriers between regions even so inclusive as a large nation or an entire continent. That men have not followed this directive, implicit in the structure of the earth, makes all the more poignant such a symposium as that in which the authors presented this paper.

In the past, the geologic factors that determine the nature, location, and quantity of various mineral resources have impelled men and nations on many occasions to bitter, even bloody, competition and on other occasions to mutually beneficial co-operation. When the problem of securing adequate supplies for normal needs moves outside the national picture into the international scene, the methods used in the attempt to solve it seem to have been determined by considerations quite outside the field of geology. Japan's need for Philippine ores and Chinese coal was one of the causes of Japanese aggression during World War II. Germany's dependence upon Sweden's iron ore, prior to and during that war, had much to do with the maintenance of friendly relations between those two nations while the other countries of northwestern Europe were the victims of German militarism.

Even so, the pattern of human relations developed in response to the necessity for exploiting mineral deposits cannot but be influenced to some extent by the geologic conditions responsible for their occurrence. A few of the highly prized or very essential minerals require such exceptional conjunction of geologic materials and processes that high-grade deposits have been formed at less than a dozen places throughout the entire earth. It is possible, consequently, for a small group of individuals within two or three nations to gain monopolistic control of them. International cartels and monopolies have both good and bad repercussions on international understanding, but the

bad effects outweigh the good in almost every instance. The British-Dutch control of nearly all the high-quality diamond resources of the world has contributed notably to the economic and cultural ties that unite The Netherlands and Great Britain with far greater durability than can be guaranteed by treaties of alliance. Fortunately, gem stones are not essential to the industrial development of retarded peoples, and the industrial diamonds that are essential to that development are so widely distributed among the rocks of the earth's crust that it is impossible for them to be subjected to monopolistic control.

In contrast, both nickel and tin are essential to technologic progress, and both are so limited in their occurrence as to make such controls possible. The development of the world's No. 1 body of nickel ore in Canada by Anglo-American capital and brains has helped to bring together Canada and the United States in mutually beneficial understanding, but the virtual monopoly of nickel has stimulated jealousies and antagonisms toward the English-speaking countries among less fortunate nations. The exploitation of the few ore deposits of tin that are both high in quality and great in quantity of tin-bearing minerals is also an obvious case in point. It is almost as though Mother Earth has perpetrated a grim joke upon mankind. Not one of the industrially mature nations has within its own borders adequate sources of this metal, so essential in a mechanized economy. Every one of the rich sources is in a region inhabited by people who until lately had little or no need for it. The stimulus toward fastening imperialistic controls upon colonial dependencies has been almost inescapable. The operations of the international cartel controlling tin have been notorious in causing friction and tension among many nations. Only the best statesmanship can make possible the future exploitation of tin ores for the mutual benefit of all mankind and the increase in harmonious understanding among all nations.

Especially critical in this consideration is the future use of the uranium resources of the earth. There are probably not more than half a dozen large, high-grade ore bodies of uranium anywhere in the world. None of these is in the United States. The geology of uranium ores is such as to drive home the fact of mineral interdependence with a vengeance. It also makes possible monopolistic control that has far-reaching significance. The wisdom required for the application of atomic energy to the future industrial and commercial development of mankind, in such a way as to promote just and harmonious relations among all nations, will prove

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to be of at least as high an order as that required to prevent the destruction of civilization by atomic weapons.

Fortunately there is increasing evidence of benign consequences deriving from the dependence of comparatively powerful nations upon weaker neighbors for essential minerals. The steel-producing corporations of the United States are already beginning to draw upon the iron ores of Cuba, Chile, and Venezuela. Until recently, this has involved little more than the exploitation of the large, high-grade foreign ore deposits for the benefit of American citizens. A new pattern is, however, emerging, as seen for example in the Volta Redonda project in Brazil. Here the exploitation of rich ore bodies, with the benefit of American capital and intellectual skills, is coupled with the industrial development of the country in which the ores are found. Opinions differ as to the economic success of this project, but it is nonetheless significant as a new chapter in international relations. In fact, without benefit of diplomatic intervention, a similar pattern is being developed in Chile, where one of the great American steel corporations is providing—for a consideration, to be sure—iron ore from its mining operations near Coquimbo, to be combined with beneficiated coal from the Concepción district. As a result, Chile will soon have steel production adequate for its current limited needs. The projected development of the extensive iron ores of the Labrador-Quebec region is another international venture that is certain to lead in several interesting directions, most of them involving closer industrial and economic cooperation between Canada and the United States.

Numerous additional illustrations of this modern trend might be cited by reference to many other strategic mineral resources, technological developments, and wholesome symptoms in international understanding, but it would probably be more helpful at this time to suggest some fundamental principles of governance for those responsible for dealing with the problems resulting from the fact of mineral interdependence. To do this, let us consider petroleum in accordance with the familiar pedagogical process known as the case method.

To date, approximately 63 per cent of all the world's oil thus far extracted from the ground has been produced and consumed within the United States. A century ago, before the petroleum industry was born, the United States possessed somewhat less than 20 per cent of the world's available crude oil resources. The disparity between those two percentages is great and startling. It

has obvious consequences. At present, American consumption of petroleum is increasing, but American reserves are rapidly diminishing. The fact that "proved" reserves of crude oil have increased somewhat in each of the past five years, so that today they are about thirteen times our current annual consumption, should not cloud the picture, with its stark portrayal of dwindling stores of this mineral fuel. As oil fields are discovered and exploited, the "probable" and "possible" reserves are systematically reduced by transfer to the category of "proved" reserves, and the date of complete exhaustion of all reserves draws ever nearer.

At the present time, the consumption of petroleum products in the United States has risen to the point where it normally exceeds domestic production and has led inevitably to the intensive development by American corporations of the oil fields of Latin America and the Middle East. This has necessarily strengthened the commercial ties with the oil-producing countries of those regions. In general, the results have been encouraging, as a consequence of the intelligence and vision of the executives of those corporations, who have almost uniformly adopted policies that contribute to the cultural and economic welfare of the communities from which the oil is drawn. To be sure, the mono-mineral economy of Venezuela, where oil is the one large source of revenue, cannot permanently endure. But the unwholesome characteristics of that economy are already being offset by the development of the iron ores in the highlands south of the Orinoco River and by intensive search for bauxite and gold in the same general area.

To complete our picture, it should be noted that the percentage of the world's oil consumed in the United States is decreasing, as other nations step up their consumption. Over the next ten or twenty years it will probably decline to 55 per cent, or even less, of the whole. At the same time the discovery and production of foreign oil by American interests are increasing. At present, Americans control approximately 62 per cent of the estimated proved crude oil reserves of the world—33 per cent in the United States, 29 per cent in foreign lands. Thus, if good international relations can be maintained between the United States and the oil-rich countries of Latin America and the Middle East, Americans may confidently expect to enjoy their fair share of the world's oil as long as it lasts.

The Next Fifty Years

Assuming now that men in general make a real effort to obey the directive established by the geologic structure and history of the earth, as set

forth in an early paragraph in this article, and seek to share as fairly as possible the rich resources of the bountiful earth, the steps to be taken will be as follows. First, get from the geologists an estimate of the total proved or highly probable reserves of each important mineral resource available for exploitation during the next fifty years throughout the world as a whole. This figure is now available, thanks to geologic research during the past fifty years. For some minerals it can be given with a high degree of precision; for others the margin of error, because of inadequate knowledge about considerable areas not yet covered by anything more than sketchy, reconnaissance surveys, is still very large. For a few mineral resources, only an order of magnitude can be indicated. Second, note for each mineral the percentages of the world's resources possessed by each nation, listing colonial dependencies and overseas territories as separate units. Third, get from the economists statistics of recent annual consumption of the products from each resource within each country and compute percentages of the world's total for each. Fourth, make estimates of the probable needs of each country for each mineral resource during the next fifty years. Here, again, there will be considerable differences of opinion among the so-called experts, and appreciable margins of error must be recognized. Nevertheless, relative orders of magnitude can be ascertained, at the very least.

With these data in hand, policy decisions may be made on a rational basis. Where the percentage of resources for a country is far greater than the percentage of need, that country should be expected to approve the exportation of the particular material to other countries. Where the percentage of resources is far less than the percentage of need, the country should expect to import the particular material from the country or countries that possess it in great abundance. Where the two percentages are of the same order of magnitude there should be no need for international transport of anything except skilled technical personnel and ideas concerning the intricate business of exploitation, processing, and conservation of resources.

On that basis, the United States should not send abroad any of the ordinary petroleum products, whereas Venezuela, Saudi Arabia, Kuwait, Iran, and Iraq should export petroleum products and crude oil, pending the construction of refineries within their own borders. This of course is what is now being done. In this instance, international understanding is on a sound basis. In the case of iron, the percentages of world reserves of all grades

of iron ore and of world consumption of steel are similar to those in the United States at the present time. But for high-grade iron ore the reserves bear a lower percentage relationship to the world's total, and therefore importation of high-grade ore from abroad is justifiable at least for a few years, pending the expected improvement in methods of utilizing the lower grades of ore. But the United States ought to be careful about exporting large quantities of iron and steel in the form of consumer goods. It is far better to export machine tools with which other people can fabricate their own consumer goods from their own iron ores than to ship locomotives and freight cars that deplete our resources of iron ore at a much more rapid rate.

A third example will suffice. The copper reserves of the United States are dwindling rapidly, and within the fifty future years for which we are taking thought our nation will be definitely a have-not nation for this important ingredient of an age of electronics. Our reserves are a much smaller percentage of the world's reserves than is our percentage of world consumption. Already we are partially dependent upon imports of copper from Peru and Chile and are even importing copper from Africa—all in accordance with the formula set forth in the foregoing paragraph. But there are other, largely unexploited reserves of copper ore in certain other countries to which we may have to turn before the end of the century. Yugoslavia, for example, possesses extensive reserves that have hardly been tapped as yet, and it might well be a wise policy to cultivate good relations with that country for this reason, quite apart from the reasons now being advanced for seeking an understanding that would be to the mutual advantage of both countries.

Incomplete though our survey has been, it is nevertheless adequate to indicate that the nature and distribution of mineral resources provide abundant opportunity for the cultivation of friendly relations among the various members of the human family. The obstacles to international understanding do not now reside in the geology or geography of the earth. They exist solely in the minds and emotions of human beings. If sincere desire for comity and justice can spread widely throughout all mankind and become dominant among the motives of men everywhere, the exploitation of mineral resources may play a significant role in expediting progress toward human welfare on a world-wide scale—the only dimension within which real and lasting welfare can ever be attained. To the abundant knowledge about min-

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eral resources now available must be added an equally abundant good will, if international understanding is actually sought.

Some of you are perhaps surprised that geologists, accustomed to think and speak in terms of millions of years, should limit their consideration of the future utilization of mineral resources to a period as short as fifty years, as we have done here. What about subsequent centuries when some of the nonrenewable resources, apparently already in rather short supply, will have been completely exhausted? The question is a fair one, and we should not be permitted to dodge it. So far as the geologic history of the earth can indicate, there is every reason to expect that our planet will continue to provide a favorable environment for creatures like ourselves throughout countless millions of future years.

There is, however, good reason for limiting our sights to a period of only a few decades. No one to-

day can foresee the results of the scientific research that will be prosecuted during the next fifty years. If we in our generation have learned how to take the nitrogen out of the air, where it is present in practically unlimited amounts, and transform it into food for plants, have discovered how to remove magnesium from sea water, where it is similarly abundant, and alloy it with aluminum for airplane frames, have even penetrated the microcosm within the nuclei of atoms and made available the energy pent therein, surely those who come after us in the twenty-first century will be able to solve the novel and unpredictable problems of their day—at least as satisfactorily as we are solving the problems of our day. Quite possibly, if we behave ourselves during the remaining half of this century, they will be our own descendants, inheriting from us the flair for scientific inquiry that has brought us so far along the road toward efficient and comfortable existence with its potentialities for "abundant" life.



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Biological Resources as a Factor in International Understanding

KARL SAX

Director of the Arnold Arboretum and professor of botany in Harvard University, Karl Sax gained his botanical knowledge in institutions at both ends of the continent (Washington State College and Harvard). As a plant geneticist, he has been interested in improved varieties and crop yields—interests that led him to appraise the adequacy of biological resources for the food requirements of the world's growing population.

THERE can be no firm foundation for international understanding until most of the world's people attain a reasonable level of economic and educational development. Today nearly two thirds of the world's 2.4 billion people live little above subsistence levels, with totally inadequate food, shelter, or medical care.¹ Most of these people cannot be expected to utilize the techniques of modern science in developing a national economy, nor can they be expected to take an active part in developing new world order until economic and educational conditions are improved.

Promises of an abundant life for all mankind are often made with no consideration of the population problem. The world's biological resources must be considered in relation to human populations. Not only do we have to provide materially higher living standards for nearly two thirds of the world population, but we must provide for an expanding population for many decades. At the present growth rate more than 200 million people are added to the world population every ten years.² Every decade resources of the world must provide for an added population equal to that of all of North America. The problem is made much more difficult by the fact that the greatest growth, or potential growth, is in the undeveloped areas of the world, where population pressure is already acute and living standards are low.

The development of the mineral resources of the world is essential for a modern civilization. Mather and Meyerhoff have shown that most of these resources are adequate for many centuries. With increasing industrialization the demands of our oil, coal, and mineral resources will be greatly accelerated, and in the case of liquid fuels, scientists are already considering the use of farm and forest products to meet our needs. As demands increase and nonrenewable resources decline, there will be

an increasing need for biological resources in industry.

Can the world produce the biological and other resources needed to redeem the Atlantic Charter pledge to achieve "freedom from want among the people of all lands"? The basic factor is the food supply, for without adequate nutrition no people can maintain the health and vigor necessary for the economic development of their resources. Before World War II the total food production was about 1,000 million tons annually, but still two thirds of the world's people did not get enough to eat. In most of the world the dietary standards are now lower than they were before the war, owing in part to an increase in population of about 10 per cent during the past decade. If the dietary level of the undernourished people of the world were to be increased to minimum nutritional standards, world food production would have to be raised at least 30 per cent over prewar levels. In order to provide optimum diets in accord with dietary standards in the United States, the world output of food would have to be more than doubled.

The world can produce more food either by increasing the yields of land already in cultivation, or by bringing into cultivation new land not now used for agriculture. The first of these two alternatives is the most feasible, since most of the fertile land that can be farmed profitably is already in cultivation. In most of the world, yields per acre can be increased substantially by the use of more fertilizers, better farm management, and the development of better varieties of crop plants. Yields per acre in different parts of the world vary enormously, as a result of differences in soil, climate, and farm management. Western Europe produces about three times as much food per acre as do the United States and Canada, partly because of more favorable weather and more intensive cultivation.

tion, greater use of fertilizers and a better system of crop rotation. Even eastern Asia produces twice as much food per acre as we do, in spite of the lack of commercial fertilizers and modern methods of control of plant diseases and insect pests. Japan's production per acre is twice that of China, and China's production per acre is twice that of India. In these Asiatic countries high production is achieved by very intensive cultivation, but with a very low output per man.

Theoretically it is possible to double the yields per acre in most of the world. Since the first world war, yields per acre in the United States have increased at an average rate of about 1.5 per cent annually, owing largely to the increase in use of commercial fertilizer, better farm practices, and the development of better varieties of crop plants. Western Europe has already developed a high degree of agricultural production without exploiting the soil resources and without excessive use of manpower. In Asia, however, high yields have been attained by intensive cultivation and increased use of manpower to the point where returns per farm worker are pathetically low. There can be no hope of high living standards if most of the working population is engaged in producing food for its own consumption. History proves that a modern civilization depends upon the release of labor from food production so that manpower can be devoted to industry, transportation, education, and the arts and sciences.

Robert M. Salter,³ of the U. S. Department of Agriculture, has estimated the possible increased yields per acre of the cultivated land of the world. By 1960 it should be possible to increase prewar yield by about 25 per cent in the United States, 30 per cent in China and the USSR, and 50 per cent in India. For the world as a whole, an increase in yields per acre of about 30 per cent is postulated. In order to attain such yields, Dr. Salter estimates that it would be necessary to increase the consumption of phosphate fertilizer eightfold, and potash eighteen times present consumption, plus large increases of nitrogenous fertilizers.

According to Salter, the prewar production of food in the world was about 1,000 million tons annually. By increasing the yields of land already in cultivation by about 30 per cent, total yields of nearly 1,300 million tons of food could be expected by 1960. Allowing for population growth, the food needs of the world are estimated at about 1,630 million tons. These estimates are based upon goals set by the Food and Agriculture Organization of the United Nations. The proposed increase in dietary standards for subsistent areas is at mini-

mum levels with a proposed increase from about 2,200 to less than 2,600 calories per day per person. Even with these limited goals the increased production of food postulated from present cultivated land is not enough to meet even minimum needs by 1960.

More land must be brought into cultivation. According to FAO estimates, the land now in cultivation totals about 2.4 billion acres, or 1 acre per person for the world population. The amount of land per person varies greatly—from about 4 acres in North America to 0.5 in eastern Asia. Dr. Salter assumes that a billion acres of tropical land which could be brought into cultivation would yield nearly 1,200 million tons of food, bringing the total production up to 2,460 million metric tons. In addition, another 300 million acres of land in the Temperate Zone would be expected to yield another 120 million tons of food, or a grand total of more than 2,700 million tons—far above the minimum needs of 1,630 million tons.

The estimates of potential increased yields from present land are conservative, but new tropical land is expected to produce more than present yields of all land now in cultivation, or nearly three times as much per acre. Most tropical areas will produce two crops each year, but the tropics present other problems in crop production. According to Robert L. Pendleton, professor of tropical soils and agriculture at The Johns Hopkins University, "except for relatively very small areas of soils from volcanic ash and recent alluvial soils, most of soils of the tropics, judged by temperate zone standards, are extremely low in plant nutrient substances and organic matter; nor are most temperature zone methods of fertilization or soil management appropriate. With suitable water conditions padi (lowland rice) is unique in being able to produce food continuously from even very poor soils; under upland conditions tree crops are the best means of utilizing most tropical soils." In general the crops best adapted to the tropics require much preparation of the land—the removal of natural forests and replacement with tree crops, or the provision of a controlled supply of water. Under favorable conditions high yields per acre can be obtained, but for many tropical crops the production per man is low.

The increased food supply from the new tropical land would consist largely of cereals, roots and tubers, sugar, and vegetable oils. According to estimates made by Charles E. Kellogg, of the U. S. Department of Agriculture, the supply of meat would increase only 13 per cent, and of milk only 5 per cent. Yet these are the very foods that

are needed most in a hot humid climate in order to maintain health and vitality.

The rapid loss of organic matter and excessive leaching of plant nutrients in most tropical soils are only part of the difficulty in developing an extensive tropical agriculture. As Clarence A. Mills⁴ has pointed out, people who live year after year under a blanket of moist heat do not maintain an active life or high vitality. "Physical and mental characteristics change from the dynamic and pushing to a more passive, let-George-do-it type." In the American tropics, at least, the problem is further complicated by political graft and corruption, which make difficult any effective rehabilitation through local government agencies.

But let us assume that Dr. Salter's goals of food production can be attained by 1960, even though there is no possibility that it will be done. John Black,⁵ professor of agricultural economics at Harvard University, in an analysis of Dr. Salter's estimates, makes the following observations:

Even with all this new land cleared and developed and farmed according to modern practices, the increased supply of meats and pulses would already have been exhausted by 1960, and if the population increased at the same rate after 1960 as assumed for the years from 1935 to 1960, the increased milk supply would be exhausted by 1970, and the increased supply of fruits and vegetables by 1980. After that, any population growth would be possible only by reducing the per capita intake of milk and meat and living more on cereals, roots and tubers, sugar, and vegetable oils. Even with the diets shifted to cereals and roots and tubers, the food supply would reach its limit within 75 years.

If anyone wants to take exception to Salter's estimates and say that they are not liberal enough, let him double them. The result will be the same except that it will be deferred.

It should now be clear that the two lines of action proposed in the Hot Springs "Final Act" [of the Food and Agriculture Organization of the United Nations] increasing food production, and increasing the power to buy food, will not be enough—that adjustment of population to resources is also necessary. Indeed, this is by far the largest part of the problem.

Yet the population problem is seldom considered in United Nations discussions of world rehabilitation, and is not even mentioned in President Truman's Point Four Program.

In surveying the agricultural possibilities of food production for a hungry world, we have not considered other sources of food and utilization. Among the more fantastic proposals is the one made by J. D. Bernal in his book *The Social Function of Science*. He assures us that it should be possible to convert coal, limestone, and air into food in sufficient amounts to feed "populations thousands or millions of times that which exist at

present." Assuming the dubious advantage of increasing the world population even a thousand-fold, what happens to the thousands of billions of people when the supply of coal becomes exhausted? Food production must be based upon renewable resources. If feasible, the exploitation of coal for food might, however, be a temporary expedient, with the hope that rapid increases in living standards would hasten the demographic transition rapidly enough so that world population would be stabilized at a reasonable level, which could then be sustained from more orthodox sources.

A somewhat more rational approach has been proposed by Egon Glesinger, chief of the Forest Products Branch of the Food and Agriculture Organization in his recent book, *The Coming Age of Wood*. Glesinger estimates that the forests of the world at one time covered about 12 billion acres, and that 8 billion acres remain, of which about 5 billion are virgin forests. He assumes that the forests of the future could yield one ton of wood per acre annually, or a total of 8 billion tons—more than twice the tonnage of food, coal, oil, and minerals now consumed each year by the present world population. By proper forest management and utilization of all forest products such yields could be maintained.

The conversion of these forest resources into fuel, power, housing, fibers, and food would, according to Glesinger, permit a high standard of living on a per capita consumption of wood of 3.5 tons per year, or 7 billion tons for a world population of 2 billion. But the world population is now 2.4 billion, so that the total production needed is 8.4 billion tons, and the estimated production is only 8 billion tons. With the aid of agriculture Glesinger's "wood economy" could relieve food shortages. But again we face the population problem and the economic problem.

It is possible to produce power from wood-burning generators, to produce sugar, alcohol, and cellulose food from wood, as was done in Sweden and Germany during the last war. But the cost was high, and the conversion of wood into cattle feed and motor fuel was discontinued after the war. Perhaps more economical methods of conversion can be developed, so that it will be practical to utilize the enormous waste of wood in present lumbering operations in many parts of the world.

Even if our forests provide only fuel, timber, and pulp, there is need for far greater production. Reforestation and forest management have hardly been started in the world as a whole. Considerable progress has been made in parts of Europe, and Sweden alone spends more money on forest ge-

netics than does the United States and Canada combined.

In many parts of the world reforestation is essential not only for a source of wood products, but for soil conservation and flood control. The demand for both wood and arable land has led to deforestation in many parts of the world, with the result that soil erosion and other consequences have ruined large areas of land. Naturally, but unfortunately, the greatest damage has been done where population pressure on food supplies is greatest—the Mediterranean countries, much of Asia, and parts of Central America. The problems of reforestation are difficult ones indeed. Dr. Glesinger has estimated that it would take half a million men twenty years to accomplish the needed reforestation from Haifa to Shanghai.

The food resources of the world are not limited to the land. It has been estimated that half of all photosynthetic fixation of CO_2 into organic matter is brought about by marine plankton and algae. According to F. N. Woodward,⁶ the oceans, acre for acre, are more productive than the land of the world. The problem of harvesting plankton would, however, require equipment, power, and labor far beyond economic returns. Even the marine fish production—an important item in the food supply of Asia and parts of Europe—is of minor importance in the total food production of the world. H. Thompson⁶ estimates the prewar marine fish production at 17.7 million tons, of which about two thirds was used for human consumption. He estimates that this production could be increased by about 4 million tons, or a total of about 22 million tons, or about 2 per cent of the prewar annual food production.

Prospects of food production by yeast factories and tanks of algae have been discussed in the popular magazines during recent years. There is, of course, a sound basis for calculating food production from such sources, and a start has been made in yeast production in the Caribbean islands. As yet there has been no great development in this field, in spite of food needs in this area. There is a limit to the amount of yeast that can or will be accepted in the human diet, even by a hungry people.

So far we have considered food and timber production on the basis of the world as a unit, but high production in one area does not now relieve hunger in other areas. Nor is there much likelihood that the food of the world will ever be equally shared. In fact, if such a policy had been followed in the past all of us would be living at Asiatic standards. It is only by considering the

demographic classes of the population of the world that we can realize the possibilities of human progress and at the same time understand the problems to be solved in the overpopulated underdeveloped areas of the world. World resources must be considered in relation to population density, distribution, and economic development.

Frank Notestein and Warren Thompson have divided the world population into three demographic groups.¹ In Group 1, including Western Europe, North America, and Oceania, birth rates and death rates are low, and population growth is approaching a stationary level. In Group 2 areas, including the USSR and the Balkans, Argentina, South Africa, and Japan, birth rates and death rates are declining, but birth rates are considerably higher than death rates, and the populations are growing rapidly. In the Group 3 areas, which include southern and eastern Asia, South and Central America, and Africa, birth rates are high and population growth is controlled by high death rates. In many areas population growth is rapid, and in all Group 3 nations potential growth rates are very high.

Only in Group 1 areas, with little more than 20 per cent of the world population, have the people made the demographic transition—the transition from a high-birth-, high-death-rate culture with low living standards to a low-birth-, low-death-rate culture with high living standards. In these modern Western nations the average annual income is \$465 per person, food consumption averages 3,040 calories per person per day, with much of it from animal sources, and life expectancy is sixty-three years. Group 2 countries, with about 20 per cent of the world population, are beginning the demographic transition. Average annual incomes are \$154, caloric intake is 2,760, and life expectancy is fifty-two years. With a few exceptions, notably Japan, these countries have resources which, if properly developed, could provide higher living standards for their growing populations. The Group 3 countries are the real problem. They contain 60 per cent of the world population—1,440 million people—with an average annual income of only \$41, less than a tenth of that of Group 1 countries. Their diet is based on an average daily consumption of 2,150 calories, and half of them get less than 2,000 calories—largely from cereals and tubers. Life expectancy is about thirty years, and half the children born do not reach maturity. About 80 per cent of these people are illiterate.

The modern Western nations have made the demographic transition by industrialization, emi-

gration, and control of the birth rate. Industrialization provided transportation, machines for the farm, and more efficient production. It also permitted the countries of Western Europe to import food and raw materials in exchange for manufactured products. Emigration to the New World relieved population pressure at home and opened up new sources of food and raw material. The decline in the birth rate slowed down population growth, and in some countries population growth has ceased. Without a reduction in the natural birth rate the demographic transition would have been impossible, because a natural birth rate and a modern death rate would result in a population growth of more than 3 per cent per year—a rate which would double a population in less than twenty-three years. No country can long maintain a population arising from a natural birth rate and a modern death rate.

Few people seem to realize the potential capacity of human reproduction. A high birth rate was necessary in primitive societies when the expectancy of life was less than twenty years. With modern death rates and primitive birth rates populations can increase very rapidly. If, for example, the birth rates in Massachusetts could be maintained at levels existing in 1800, together with 1950 death rates, the population of the commonwealth would increase from less than 5 million in 1950 to more than 150 million in less than one hundred years. In two hundred years the population would exceed 2.4 billion, and in five hundred years there would not be standing room for all on the surface of the earth. Yet in Massachusetts we are told that "Birth control is against God's law!"

With the exception of Japan, there are reasonable prospects for the Group 2 countries to make the demographic transition. But the prospects for Group 3 nations appear to be dim, indeed, and are quite hopeless so long as there is war or threat of war among the major nations of the world.

Half the people in the world live in Asia, but they live neither well nor long. Population density is high, with little more than half an acre of cultivated land per person. Can these people escape hunger and poverty by following the path of the Western nations and eventually stabilize populations at high living standards? Considerable industrialization is possible, but one of Europe's greatest benefits of industrialization was the import of food and raw materials. Few countries have surplus food in amounts needed by Asia, and most of them have, or will develop, their own in-

dustries. Emigration on a sufficient scale to be effective in reducing population pressure is impossible. It would mean moving 5 million Indians every year, and unless they were established at high living standards in the country of destination they would soon create the same population pressure found in India. Control of the birth rate would seem to be the only solution, but people who live at subsistence levels do not adopt birth control techniques, even in our own country.

Let us assume, however, that food production could be stepped up in Asia, with the technical aid of the Western nations, to an increase of 1.5 per cent per year. The first effect would be a reduction in the death rate. With the inevitable introduction of public health measures the death rate would decline still more. But the birth rate would actually rise for a period of time, because a larger proportion of women would live to reproduce. It is possible, as in Puerto Rico, that the population could grow at the rate of 3 per cent per year. Long before birth rates dropped to replacement levels the population would have increased at least three-fold—from over 1 billion to more than 3 billion. No country has made the demographic transition with less than a threefold increase in population, and it is unlikely that Asia can do better. But Asia cannot support a population of 3 billion on known available resources, and even with fantastic increases in food production the resources would provide little more than subsistence living and continued high birth rates.

If this point of view seems unduly pessimistic, take a look at Puerto Rico. We have introduced education, public health, a stable government, and a subsidy economy to the tune of about 50 million dollars a year. When we acquired the little island fifty years ago the population was about a million. Today it is well over 2 million, but most of the people live little better than they did fifty years ago, although they do live longer. Birth rates remain at about 40 per thousand, whereas death rates have been reduced to less than 12 per thousand—a net gain of nearly 3 per cent a year. At the present rate of growth the population of Puerto Rico will double again in less than 30 years.

It should be evident that the population problem is the basic factor in the development and utilization of the world's biological resources—including man. Population pressure in the economically backward areas of the world makes impossible the full development of human resources. When half the children born never reach the age when they can contribute to the economy of the nation, human resources are wasted. Poverty pre-

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vents education and as a result the inability to utilize the arts and sciences of the modern world. Low living standards retard the accumulation of material resources for public works and industrial development.

Yet the biological and mineral resources of the world are adequate to provide reasonable living standards for all the world's people if the demographic transition is made rapidly. But it cannot be done if there is war or threat of war among the major nations of the world. Nor can it be done by trying to put into effect the Point Four program in all the distressed areas of the world simultaneously. The cost of even a limited program of world rehabilitation would amount to hundreds of billions of dollars. So long as the industrialized nations must spend fantastic sums for rearment, there will be no surplus for a Point Four program. A strong United Nations organization or a limited World Government now appears to be the only way to avoid the costly rearment program and the even more costly third world war. Perhaps it is already too late.

If the world can return to peace, the rehabilitation program should be started with the nations that have already begun their demographic transition. To try to do more would be too great a drain on the 20 per cent of the world's people who have made the transition, and an inadequate effort would be worse than no program at all. As the Group 2 countries reach demographic and economic maturity they would join the modern Western nations in a program to rehabilitate the undeveloped areas, and these areas in turn would contribute as they become able to do so. No efforts should be made to help eastern and southeast Asia until the rest of the world is strong enough to make a real contribution. An inadequate program can only intensify the problem and make any real solution more difficult. Strong opposition has been voiced to proposals that nothing be done to improve public health in Asia or to send food to India and China, but no rational solution has been proposed by the critics. Perhaps there is no rational solution.

Any effective rehabilitation program in undeveloped areas must include all the essential factors needed for the demographic transition. It is futile to introduce public health measures if the only effect is to keep people from dying of disease so that they may die of malnutrition and starvation. There is no merit in increasing food production if the only effect is a larger population living at subsistence levels. The introduction of industriali-

zation can have no permanent benefit unless the people possess the knowledge and skills necessary to maintain an industrial culture. Public health, improved agriculture, industrialization, and education are all essential, but they must be developed simultaneously if they are to be effective.

The potential mineral and biological resources of the world could provide adequate living standards for all the people of the world if they could be developed rapidly enough. We can expect continued progress in the development of world resources and the development of new techniques in industry and agriculture. At the same time rapid advances must be made in the field of political and social relationships. We must also consider spiritual values, but there is no need to abandon science and revert to ignorance and mysticism. The nature of our spiritual needs has been well summarized by the Chinese statesman and philosopher Hu Shih, in *Whither Mankind*,⁷ as follows:

It took over a thousand years for a portion of mankind to emerge from the civilization based upon the religion of defeatism which glorified poverty and sanctified disease, and slowly built up a civilization which glorifies life and combats poverty. This change has come by the development of science and machinery.

The difference between the Eastern and Western civilization is simply a degree of success or failure in the process of breaking away from the medieval ideas and institutions which once ruled the whole world.

Civilization sank into medieval darkness when man became weary of the task of fighting his natural environment and sought refuge in the life of the spirit.

But that very self-hypnotizing philosophy is more materialistic than the dirty houses they live in, the scanty food they eat, and the clay and wood with which they make images of their Gods.

That civilization which makes the fullest possible use of human ingenuity and intelligence in search of truth in order to control nature and transform matter for the service of mankind, to liberate the human spirit from ignorance, superstition and slavery to the forces of nature, and to reform social and political institutions for the benefit of the greatest number—such a civilization is highly idealistic and spiritual.

The realization of these spiritual values will depend upon the intellectual resources of mankind.

References

1. *Point 4*. Washington, D. C.: U. S. Dept. of State (1950).
2. *World Population Estimates*. O.I.R. Report 4192. Washington, D. C.: U. S. Dept. of State (1947).
3. DE TURK, E. E. *Freedom from Want*. Waltham, Mass.: Chronica Botanica (1948).
4. MILLS, C. A. *Science*, 110, 267 (1949).
5. BLACK, J. D., and KIEFER, M. E. *Future Food and Agricultural Policy*. New York: McGraw-Hill (1948).
6. U. N. Economic and Social Council (1949).
7. HU SHIH. In C. A. Beard (Ed.), *Whither Mankind; a Panorama of Modern Civilization*. New York: Longmans, Green (1934).

Anthropology in Trust Territory Administration*

PHILIP DRUCKER

The author, who is a lieutenant commander in the Navy, has been field, social, and scientific affairs officer on the staff of the Deputy High Commissioner, Trust Territory of the Pacific Islands, since 1948. After taking his Ph.D. in anthropology in 1936 at the University of California he became a National Research Fellow in the archaeology of the Northwest coast at Columbia, later becoming an assistant in the Bureau of American Ethnology of the Smithsonian Institution. He has recently been in Suva, in the Fijis, to assist in the transfer of fifty-four Micronesian medical and dental students from the schools on Guam.

THIS article, dealing with the utilization of anthropology in the administration of the Trust Territory of the Pacific Islands, concerns but one of the many problems of Micronesia that might be discussed. I have selected the topic in the hope that it may be of maximum interest—even social scientists who are not specialists in Oceanic cultures may wish to know how the science has been utilized in the administering of a population of some 50,000 people, differing markedly among themselves in language, culture, and in acquisition of Western materials and concepts. Having had the good fortune to be assigned for the past two years to the Trust Territory administrative staff—a vantage point from which I could observe policy and practice both as an anthropologist and as an administrator—I offer this summary of how anthropology has been utilized and shall venture some appraisal of what it has contributed in the carrying out of a very complex task. It seems well to remark, before taking up the main theme, that this paper is not intended as a defense of administrative policy and practice, but is rather a summary of facts relating to the practical application of the science of anthropology. Impartially judged, the Navy's record of achievement during the five years of Trust Territory administration is sufficiently creditable so that no defense is really called for.

* Based on a paper presented at the annual meeting of the American Anthropological Association, December 29, 1950, at Berkeley, Calif. The opinions contained herein are those of the writer, and do not represent an official statement of policy by the Navy Department, nor do they necessarily represent the opinions of the naval service in general.

In World War II, when the Allied forces started to fight their way along the long road from the South Pacific to Tokyo, their strategists were very much aware that squarely athwart that road lay a terra incognita that had been in possession of the enemy for several decades. This was the part of Micronesia taken by the Japanese from Germany in 1914, and later assigned to Japan as a mandate by the League of Nations. It included the Marshall and the Caroline archipelagos, and all the Marianas Islands save Guam. The sea area over which the scattered atolls and islands occur is roughly equivalent to the land area of continental United States. Yet, due to the Japanese policy of exclusion of foreigners, very little was known of those islands, their populations, or resources. The only certainty was that Japanese Micronesia would be heavily fortified and strongly defended. Warfare in that area would surely stress naval action and amphibious assaults. The U. S. Navy was therefore delegated the command function in planning the drive through the area and, along with command, the subsidiary responsibility for military government.

Military government is always a difficult and complex problem. According to the rules of modern warfare the civilian population must be supported, and medical, sanitary, and similar services must be provided, until the civil populations can resume these functions for themselves. In addition, of course, there is the potential danger of espionage and guerilla action to be guarded against. For most parts of the world sufficient information on the nature of the population, economic and social structures, the people's probable

attitude of hostility or friendliness, and the like were abundantly available. From the Japanese Mandate very little information was at hand. This, therefore, was the problem that fell to the Navy with the military government assignment: to make plans for the governing of almost unknown peoples in a little-known area.

A saving fact, although it is one that is not widely recognized outside the service, is that the Navy for many years has been accustomed to dealing with complex technical problems and has an established policy of calling on experts for advice. Like any other large organization, the Navy likes to have its own experts—for example, in engineering, naval architecture, and electronics—but it has never hesitated to call on qualified civilian specialists when the need arose. Almost from the first, therefore, in laying plans for military government of the Japanese Mandate the Navy called on anthropologists as the specialists who had or could assemble necessary information on the Micronesians and their islands. All possible sources of information were drawn on, of course, but professional anthropologists played a prominent part in the task of assembling and evaluating data. G. P. Murdoch, of Yale, was one of the principals in this task. The information assembled in this manner was subsequently published in a series of military government *Handbooks* which set the standards for military government in Micronesia. Social and economic patterns and problems of native peoples, as well as the appraisal of attitudes—particularly the highly important presumption that the natives would be nonhostile—were made available to the future military governors.

As these data, coordinated principally by anthropologically trained specialists, began to take coherent form, the training of prospective military government officers was begun. The candidates for military government schools included a high proportion of anthropologically and sociologically trained officers, as well as such men as could be found who were familiar with Oceania and the Orient. The anthropologically slanted materials of the military government *Handbooks* formed a key part of the curricula of these schools. Consequently the groundwork was laid for the sympathetic governing of the natives of Micronesia.

Military government of the ex-Japanese Mandate during the war and immediately after was based on policies that very clearly showed the importance of the anthropological point of view used in assembling and appraising the basic information on the areas. Admiral Nimitz' basic military government proclamations stated explicitly that

native culture and customary law were to be respected to the maximum extent possible—this long before the United Nations stressed the same concept in the basic agreement for treatment of trust territories. This emphasis on cultural tolerance apparently was derived from the anthropological approach and the utilization of anthropologically trained personnel in planning. At times, it is true, the carrying out of these policies was beset with difficulties. During hostilities, military operations obviously had to have priority over everything else. Military government teams were sometimes short of personnel; they often had temporary shortages of supplies and equipment. In places where large populations of enemy nations were found, security requirements had to take precedence over the policies for the treatment of Micronesian natives. In each of the major districts except the Marshalls, there were many more Japanese, Okinawans, and Koreans than there were natives. These populations had to be segregated and eventually repatriated before full emphasis could be given the welfare of the Micronesian peoples.

After the war it became apparent that for the time being the Navy was the logical agency to administer the former Japanese Mandate for the United States government. The Navy had personnel and materials in the area, and it had ships, planes, and communication facilities for supporting the administrative units. Even though it was foreseen that its administration would be for an interim period only, the Navy established a special training school, the School of Naval Administration, or SONA, as it was sometimes called, for prospective military government officers. The candidates for this school were selected from the people who had had military government experience during the war and those with a particular interest in, or special qualification for, such work. These men were trained in a program that was once again based in great part on the anthropological approach to the administration of native peoples.

Felix Keesing, as an authority on modern Oceanic and Far Eastern cultures, was requested to aid in formulating the curriculum and to assist in the instruction of the prospective military government officers. The training given stressed the anthropological approach, not with the idea of making the officers professional or even amateur anthropologists, but to give them the point of view of anthropology, especially an appreciation for and a tolerance of cultural patterns and attitudes very different from our own. There were, of course, many fields other than anthropology with which



Kapingamarangi is one of the two atolls in Trust Territory inhabited by Polynesians, rather than Micronesians. Anthropologists of the Navy-supported CIMA and SIM programs have made intensive studies of the culture of these people. Here Admiral D. C. Ramsey, USN, during a tour of inspection while serving as High Commissioner, Trust Territory of the Pacific Islands, observes a skilled mat-weaver. (Official photograph, U. S. Navy.)

the prospective military government officers had to become familiar: the aspects, for example, of international law affecting non-self-governing areas, and the ramifications of the detailed obligations of the United Nations Agreement, basic features of public health programs in tropical areas, some notion of economic problems of tropical Oceania, and many similar matters.

The School of Naval Administration continued in operation for about three and a half years to provide trained officers for the administration of the Trust Territory and to make replacements available as tours of duty were completed. It may be noted in passing that although the administration of Trust Territory officially became civil government rather than military government upon the Congressional approval of the United Nations Trusteeship Agreement and the Presidential Proclamation of the Trusteeship status of the former

Japanese Mandated territory on July 18, 1947, the aims of the naval government and the training given at the School of Naval Administration had been aimed from the first at government of civil rather than military type.

At the close of the war it had become apparent that considerable assistance would have to be given to the native economies to enable the people to achieve, and eventually to surpass, the standards of living to which they had become accustomed during the Japanese regime. Although there were widely varying degrees of acculturation among the native communities—to a considerable extent depending upon nearness or remoteness of the Japanese centers of population—even the remoter, less Westernized groups had certain needs such as those for iron and steel tools, cloth, tobacco, soap, and kerosene that made it essential that they have commercial relations with the outside world.

For most of the area these importations had come to be basic needs, not just luxuries. The United States Commercial Company, an agency of the Reconstruction Finance Corporation, rather than the Navy, was at first responsible for the economic rehabilitation of the area. It was this organization, therefore, that made the first large-scale survey of economic conditions and potentialities of the Trust Territory.

A number of anthropologists, as well as botanists, agriculturalists, geologists, and other specialists, were called on to assist in the investigation. The results of the economic survey were utilized as soon as they became available, by the naval administrators in the field as well as by the U.S.C.C. economists. They were also drawn on by the faculty of the School of Naval Administration. The anthropological data in these U.S.C.C. economic reports were recognized as being of great importance for administrative purposes. This recognition was apparently an important factor in obtaining naval support of the program known as Coordinated Investigations in Micronesian Anthropology (or CIMA) in which some forty ethnologists, linguists, and geographers participated. CIMA was made possible by a large grant from the Office of Naval Research and by authorization by the Navy for transportation and logistic support of the participants. The Pacific Science Board of the National Research Council directly administered the program. As a result of CIMA an extensive series of reports has been prepared which will make Micronesia one of the better-known parts of Oceania. CIMA subsequently has been modified to Scientific Investigations in Micronesia (or SIM) to permit the inclusion of studies in natural history: botany, entomology, hydrology, and the like.

Partly as an outgrowth of the CIMA project itself and in part as a logical follow-up of the Navy's recognition of the value of anthropology in naval administration, a new program was developed. This was one in which anthropologically trained individuals were employed for assignment to the various district administrators. At the present time such Anthropological Field Consultants, as they are formally titled, are serving as trained fact-finders and researchers in problems of administrative significance in all the districts of the Trust Territory except the Northern Marianas, where through a special arrangement Alexander Spoehr carried on his own research over a period of a year but also acted as advisor to the civil administrator.

An example or two of the administration's approach to specific problems, and the way that anthropological concepts have been utilized in the



Ngulu Island, in the Western Carolines, is one of the more primitive islands of Trust Territory. Captain (now Rear Admiral) F. C. Greaves, MC, USN, checks over medical supplies with a Navy-trained health aide. (Official photograph, U. S. Navy.)

solutions, may be of interest. One such problem related to the mining of phosphate deposits on the island of Angaur in the Palau group. Angaur's rich phosphate deposits had been mined in a small way during German administration before World War I, and the mining had been intensified and developed into a major program during the Japanese period. At the conclusion of the war it was decided at a high level of authority that the needs of the Japanese people for fertilizers for the production of foodstuffs were so acute that the mining on Angaur for Japanese use should be resumed. The alternative appeared to be either food shortages and unnecessary suffering for Japanese civilians or vastly increased costs to the American taxpayer for their support. The naval administration was, however, insistent on the principle that the natives of Angaur should benefit from the mining operation and should be protected against any major damage to their farmlands. As it appeared that the Japanese would continue to need to draw upon the Angaur deposits for some time, a special study was ordered. A preliminary investigation was made by an anthropologist and a conservationist, who spent several weeks on Angaur in the fall of 1949 studying the agricultural potential of the island, patterns of land use and land ownership of the natives, and social and economic effects of the mining operation. At the conclusion of the investigations, the specialists reported that continuance of the mining appeared to be against the best interests of the Angaurese. They considered that a certain part of the phosphate-bearing area was necessary to the natives for production of foodstuffs, and that there-

fore mining of that area would cause social conflict by creation of a dispossessed, landless segment of the community. Another point of major significance was their belief that continued mining might damage irreparably the island's fresh-water supply by permitting the intrusion of sea water into the island water lens.

As a result of this report a conference was arranged among representatives of the Angaur community, of the Supreme Commander for the Allied Powers in Japan, who was responsible for supervising the phosphate mining, and representatives of the naval administration. It is worth remarking here that the SCAP representatives at the conference, although convinced that the welfare of 80,000,000 Japanese was a more important consideration than that of 350 natives of Angaur, were from the outset in accord with the principle that no major damage to Angaurese economy or society should be caused by the mining. Their position, based on engineering and geological studies they had made, was that no major damage to the island would result. As an outcome of this conference it was decided that further investigation would have to be made to verify one or the other of the two conflicting opinions. It happened that it was not anthropology but another science that resolved the critical problem as to whether further mining might cause permanent damage to the island and its economy: a committee of hydrologists, specialists in island water supply, called on by the Trust Territory Administration and SCAP, gave the answer. Their report made clear that measures should be taken to protect the island's water supply not only against damage from continuation of the mining, but from gradually increasing contamination begun as a result of the deep mining by the Japanese prior to World War II. At a subsequent conference, at which once again the Angaurese, SCAP, and Trust Territory Administration were represented, an agreement was reached to the effect that mining might be continued provided that arrangements were made to prevent intrusion of salt water into the island water lens. The hydrologists recommended that this be done by filling not only the new pits but the old ones excavated prior to the war.

Another feature of the agreement was that the one agriculturally valuable area in the phosphate beds should be exempt from mining. The scale of royalties to be paid to the natives of Angaur was increased also. These new proposals were then presented to the Angaur community and were accepted by them as satisfactory. A special achievement—or at least we so regard it—is that the

royalties, except for an Emergency Relief Fund which the Angaurese wanted readily available, and a Business Loan Fund for commercial ventures, are being paid into a Permanent Trust Fund, which will bring in a sizable sum annually, long after the mining has ceased. Subsequently, in order to work out a practical, just system of distribution of payments from the Trust Fund, a very detailed study was ordered by the administration, in which the Anthropological Field Consultant of the Palau District made a complete analytical census of the Angaur community. Since the Angaurese had been firm in insisting that they wanted the clans recognized as the landholding entities, and wanted the payments to be made to the clans rather than to lineages or to individuals, this census recorded the clan membership of each person. Clan affiliation through adoption or a sort of "honorary membership" was differentiated through genealogical check, and rights to succession to clan titles were also recorded. All in all, the anthropologist, Harry Uyehara, did a first-class piece of field research, through which the administration ensures an equitable distribution of the phosphate royalty benefits, one that accords with the expressed wishes of the natives and with their social structure.

The Trust Territory Administration has also had special studies made of the problems of the natives of Bikini, in the northern Marshalls, in order to find a way to help them adjust satisfactorily to a new home. The selection of Bikini Atoll for the A-bomb tests was governed by numerous technical considerations. To resettle the little group of native inhabitants became the task of the administration. Although it would have been simple enough, and legal enough according to Western thinking, for the United States government to acquire title to Bikini through condemnation proceedings and to pay for the lands at a justly appraised cash value, the view taken by the naval administrators from the outset was that such a procedure would be to the detriment of the ex-Bikinians. The real need of these people was for land—it was considered far more beneficial for them to get lands of their own in exchange for their former holdings than to receive cash. But there is no point in robbing Peter to pay Paul; the land had to come from unoccupied areas in the public domain. At the Navy's request, Leonard Mason, who had worked in the Marshalls during the U.S.C.C. economic survey, visited the ex-Bikini group in their temporary location on Rongerik. Rongerik Atoll, Mason found, was quite inadequate. Chiefly on the basis of his recommendations, the group was moved to

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Kwajalein and subsequently to Kili, a small but fertile island in the southern part of the Ralik Chain that had been a commercial plantation during the German regime and throughout the Japanese period.

The group got off to a good start—the Navy built houses and cisterns, and provided tools, utensils, and a store of foodstuffs for the initial period of adjustment—and they seemed anxious to begin cleaning the underbrush from the groves and to start making copra and planting gardens. Before a year had passed, however, administrative officers on periodic visits noted and reported to the civil administrator that the people were dissatisfied with Kili, and were making little effort to get the island back to normal production of copra and food. The fact that for some months bad weather each time a ship called had prevented lifting of their copra had further disheartened them. It was decided that an anthropologist should be sent to try to determine

just what the ex-Bikinians' difficulties were. This interesting assignment fell to me, as I was then in the Marshalls studying various aspects of native adjustment to modern economic and administrative conditions. The results of the study, after several weeks' discussions with the people, singly and in groups, and a fairly minute examination of the island of Kili itself, formed the basis of a series of recommendations, at present being implemented, which it is believed will help the A-bomb exiles to make an adequate adjustment to their new home.

Still more recently, a party consisting of an anthropologist, an entomologist, a medical officer, and a dental officer, a laboratory technician, and interpreters was sent for a stay of two weeks to war-devastated Woleai Atoll, in the Central Carolines between Truk and the Palau, to investigate conditions there more intensively than is possible in the course of the quarterly routine administrative trips.

These examples should suffice to show that the



These Ngulu ladies wear the traditional dress of their island. Ngulu Island is one of the few places in Trust Territory where the aboriginal grass skirts are still worn. (Official photograph, U. S. Navy)

naval administration of the Trust Territory has made a consistent effort to utilize anthropology and the anthropological approach to social, political, economic, and other problems of the native population. This is part of a definite policy of calling in specialists as consultants on technical problems; anthropologists are not the only scientists so chosen, for many entomologists, botanists, hydrologists, agriculturists, and other experts have carried out investigations in Trust Territory, either as members of the staff, or as participants in Navy-sponsored research programs. The ultimate goal, so far as the Navy is concerned, is not the accumulation of data in a particular field of science, but the integration of those data into policies and programs that will contribute to the welfare of the 50,000 Micronesians and ease the shock of adjusting in a few decades from a neolithic way of life to the whirl of the atomic age.

There is, of course, another side to the coin. The utilization of anthropology has been described. It may be worth while to summarize briefly what anthropology has contributed to resolving administrative problems of the Trust Territory. It seems clear that in the beginning, in assembling information and recommending policy for military government, anthropology, and anthropologists, contributed a good deal, and their influence has lasted. Those anthropologists who have belonged to the organization, such as the Anthropological Field

Consultants, have offered solutions to specific problems and have at times been able to recommend broad policies for native welfare. Of the anthropologists who have come out of the various Navy-sponsored research programs, some have felt that they had some obligation to use their research techniques and background to investigate problems of administrative concern—land ownership concepts, native economy, adjustments in political organization, law and sanctions, and the like—and others have not. The Trust Territory Administration has deliberately avoided any suggestion that it wanted studies aimed at some specific application. It has been left up to the individual scientist to decide whether he should devote at least some of his field time to problems of concern to the administrators. In other words, it has been left to the fieldworker to decide whether his responsibilities as a citizen, his concern with furthering the profession, and his interest in his native collaborators will make him give some consideration to present-day problems, though his main interests may be in questions of purely academic concern. The rather obvious conclusion is that the science of anthropology has demonstrated that it *can* have great utility in carrying out the obligations of our government in administering for the well-being of the native peoples of Trust Territory; whether it does or not is between the individual anthropologist and his conscience.



[Continued from page 294]

LINDLEY, J. *Vegetable Kingdom*. (3d ed.) London (1853).

LINNAEUS, CAROLUS. *Species Plantarum*. Holmiae (1753).

LOWE, J. L. *Lloydia*, 2, 235 (1939).

MARTIN, G. W. *Univ. Iowa Studies Natural Hist.*, 18 (Suppl.), 1-64 (1941).

MERRILL, E. D. *Mem. Brooklyn Botan. Garden*, 4, 57 (1936).

—. *Torreya*, 43, 50 (1943).

PERSOON, C. H. *Synopsis Plantarum*, Vol. II. (1807).

POUND, R. *Trans. of Saccardo's Il Numero delle Plantae Am. Naturalist*, 28, 173 (1894).

RAMSBOTTOM, J. *Ann. Repts. Smithsonian Inst.* 1945, 313 (1946).

SACCARDO, P. A. *Atti congr. botan. intern.* (Genova), 57 (1892).

SMIRNOV, L. A. *Soviet. Botan.*, 5, 39 (1943).

SMITH, G. M. *Cryptogamic Botany*. New York: McGraw-Hill (1938).

SWINGLE, D. B. *General Bacteriology*. New York: Van Nostrand (1940).

—. *Plant Life*. (2nd ed.) New York: Van Nostrand (1942).

STEUDEL, E. G. *Nomenclator Botanicus*. (1821-24).

TIPO, O. *Chronica Botan.*, 7, 203 (1942). (Outline published in H. J. Fuller's *The Plant World*, 55-58 [1941].)

TURRILL, W. B. *Kew Bull.*, 1949, 453 (1949).

UPHOF, J. C. T. *Die Pflanzengattungen, Geographische Verbreitung, Anzahl und Verwandtschaft Aller Bekannten Arten und Gattungen im Pflanzenreich*. Leipzig: Weigel (1910).

VINES, S. H. *Brit. Assoc. Advancement Sci., Rept.*, 916 (1900).

WILLIS, J. C. *A Dictionary of the Flowering Plants and Ferns*. (6th ed.) Cambridge, Eng.: Cambridge Univ. Press (1931).

—. *The Course of Evolution*. Cambridge, Eng.: Cambridge Univ. Press (1940).

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New Light on Ancient America

RALPH LINTON

*Before entering the teaching profession, the author spent many years as a museum curator and field collector in both ethnology and archaeology. He has written numerous books, including *The Archeology of the Marquesas Islands*, *The Tanala, a Madagascar Hill Tribe*, *The Study of Man*, and *The Cultural Background of Personality*. Dr. Linton is at present Sterling professor of Anthropology at Yale.*

TO ANYONE not a professional historian, the study of the past offers two peaks of interest. One of these comes at the point where written records are complete enough so that individuals emerge as personalities. The other lies in that part of the past for which there are no written records and where events have to be reconstructed with all the skill of a fictional crime investigator. Between these two points lies an arid waste of names, dates, and battles significant only to the specialist. The extent of this no man's land varies greatly in different parts of the world. In Egypt and Mesopotamia we can feel the presence of real people five thousand years ago. In the New World, where writing was limited to the impersonal calendrical records of the Mayas and the half-mnemonic pictographic scrolls of the Mexicans, history, in the technical sense, can hardly be said to exist before A.D. 1500.

From the scientific point of view, the lack of written records in America has been a far from unmixed evil. With no inscriptions to search for or decipher, American investigators have turned to a steady improvement of archaeological methods, especially as these apply to dating the past. Although scientific archaeology originated in Europe, American methods of excavation and recording have become as good as any in the Old World, and our scientists have contributed at least two dating techniques more exact than any developed abroad. One of these employs the varying annual growth in tree rings as a clue to the age of structures in which wood or even charcoal has been found. It has made possible the establishment of culture sequences in southwestern United States, but attempts to apply it elsewhere have given rather inconclusive results. It also has the disadvantage of being applicable to only a small section of New World history. The earliest dates

derived from it so far do not go back beyond the year 300 B.C.

The second dating technique is a by-product of modern atomic studies. It rests on the discovery that a radioactive isotope, carbon 14, is constantly being produced in the earth's atmosphere by the collision of cosmic rays with nitrogen atoms. The proportion of this isotope to other carbon in the atmosphere seems to be constant at all times and places. Atmospheric carbon is assimilated by living organisms, whether plant or animal, but the assimilation ceases at death. Since carbon 14 has a half-life of $5,568 \pm 30$ years, by determining the percentage of this isotope in the total carbon of a specimen, it is possible to date it with a comparatively small margin of error. The method cannot be used for material more than 25,000 years old. Dates based on uncharred wood or bone also must be taken with some reservation, for these substances may exchange carbon with deposits in which they are buried. In spite of these limitations, the technique is the best tool so far made available for dating early remains. Even the first series of dates to be published¹ have greatly increased our knowledge of ancient America. In connection with recent archaeological discoveries, especially those in Alaska, the carbon-14 technique should make it possible to solve the puzzle of American origins.

It may be said at once that none of the new discoveries throws doubt on the long-accepted theory that the first settlers of America came from Asia by way of Alaska. In view of the flurry aroused by the heroic voyage of the *Kon-Tiki* (and the resultant best seller), one may expect a resurrection of myths of trans-Pacific settlement. The Pacific is a large ocean, however, as many Americans can now testify, and to cross it anywhere south of the Aleutians would have required a skill in boat-

building and seamanship altogether out of line with the simple, food-gathering, hunting cultures indicated by the earliest remains everywhere in North and South America.

II

Since the leader of the *Kon-Tiki* expedition has given professional anthropologists somewhat less than their due in his delightful book, the question of trans-Pacific contacts may deserve a brief discussion. Far from denying that Polynesians reached America, anthropologists have accepted this for many years, and any ethnographer can point out a small series of what appear to be Polynesian culture traits scattered along the west coast of both North and South America. The presence in Polynesia of the sweet potato, complete with its Quechua Indian name, also indicates that some of the voyagers who reached America returned. It is even possible that a few generations before the Spanish conquest Inca rafts reached Polynesia. There were Inca stories of islands to the west on a bearing that would have taken voyagers close to Easter Island. These contacts were certainly late, however, and theories of the settlement of Polynesia from South America or vice versa seem like the purest fantasy to anyone familiar with the cultures and languages of the two regions. The Polynesian languages belong to a single linguistic stock which extends across Oceania and southeast Asia to Madagascar, but which has no American representatives. Of the numerous crops grown in the two areas, only the sweet potato and gourd were common to both. (There is no evidence that coconuts were a South American crop in pre-Columbian times.) The Peruvians were the most expert weavers in the world and were making good cloth by at least 2000 B.C.; the Polynesians made only mats. The Peruvians were expert potters; the Polynesians made no pottery. The Polynesians used the adze as their main tool; the Peruvians did not use it. This list of differences could be continued for several pages.

A number of recent discoveries throw light on the beginnings of American settlement. After the first period of enthusiasm, archaeologists gave up hope of finding really early human remains in the New World. Hopes were revived in 1927 when a javelin point of a distinctive type (Folsom) was found in unquestionable association with the skeleton of an extinct species of bison. Since then a large number of other finds have established the presence of man in America at a time when an extensive fauna of large animals now extinct was flourishing. Attempts to give exact dates to these

finds by geological methods have been inconclusive—the geologist's techniques are more effective for long than for short time intervals. The new carbon-14 dates, which are consistent enough to be highly probable, indicate that it was the animals who survived to a late date, rather than the human beings who came early. The earliest sites so far tested do not go back more than 10,000 years. Since these are within the limits of the United States, some time must be allowed for the migrants to get so far south, but a maximum age of 12,000–15,000 years for the first American migration is indicated.

This date was near the close of the last glacial advance, and the conditions for migration were auspicious. The drop in sea level that went with each glacial period had closed Bering Strait and substituted for it a broad land bridge. Geological and paleontological evidence indicates that this land bridge was never glaciated. For a time, at least, much of it seems to have been open grassland, providing pasture for huge game herds and consequent abundant food supply for people who had learned to hunt large animals. Discoveries made in Alaska within the past three years indicate that the Folsom culture existed there at an early date and may well have been that of the first migrants.²

At the time of this first migration, much of Alaska was ice-free, because, apparently, snowfall was so light that ice could not accumulate. The higher mountains were under ice, however, and the glaciers of the Coast Range were so extensive that it would have been almost impossible for migrants to make their way southward along either the Yukon Valley or the west coast. It seems likely that the first wave of migrants followed the coastal plain, much wider then than now, north and east, until they had outflanked the Brooks Range and reached the valley of the Mackenzie.² Once the mountains had been turned, the way lay open for rapid travel southward. There was an ice-free corridor along the eastern side of the Rockies, and, equally important, the sort of game on which the migrants depended ranged over the whole of the Great Plains from Alaska to Mexico.

This part of the picture seems fairly clear. From this point on the situation becomes much more complex and confused. Although the archaeological evidence for the next three or four thousand years is scanty, it shows the existence of a surprising variety of cultures. In attempting to reconstruct the culture history of this period, the greatest handicap is our lack of precise information on the ecological areas of North America during late glacial and immediately post-glacial times, and

especially regarding the movement of these zones in response to short-term climatic changes. Hunting, food-gathering societies are as dependent upon their natural environment as any other mammalian species. Having developed the techniques needed for exploiting the food and materials provided by a particular ecological configuration, they are reluctant to migrate to territories where new techniques will have to be invented or borrowed. They will move with a particular ecological area as its position shifts in response to climatic changes and they will not push out from it into areas of markedly different ecology until forced to do so by population or other pressures. To a Plains people, a forested area presents a migration barrier nearly as effective as a mountain range or arm of the sea. The Folsom migrants would thus have tended to spread southward over the whole of the Great Plains before they tried to penetrate the Eastern Woodlands or the Rocky Mountains or intermontane plateaus. More important still, the southern limits of their range probably coincided with those of the big game they were accustomed to hunt. Since this game never ranged as far south as the Isthmian region, the odds against Folsom migrants reaching South America are heavy.

From approximately 8000 B.C. until perhaps 2000-3000 B.C., the Plains seem to have been occupied by the Folsom and Yuman cultures. The relation of these two is still imperfectly understood, but they were certainly contemporaneous over a long period. Their creators were linked by the fact that both were big-game hunters adapted to open plains. During much of this time, however, there were other cultures to the west and south of the Plains. At the time this is being written the oldest carbon-dated material, about 7000 B.C., comes from a cave in Oregon and definitely does not belong to Folsom or Yuman. The Cochise culture of Arizona goes back to at least 5000 B.C., and a surprising variety of other Plateau cultures seems to belong to nearly the same period. All these cultures were markedly inferior to Folsom and Yuman in flint-working, but most of them used grinding stones of the mano-metate variety. Their archaeological inventories suggest adaptation to a semiarid environment, much like the present one in this region, with dependence on wild seeds and small game. The Plateau ecology extends far into Middle America, and the first migrants to reach South America probably had cultures of this general type rather than those adapted to big-game hunting.

The origin of these Plateau cultures presents an interesting problem. No remains that can be linked

with them have been found in Alaska or along the northern Plains migration route. They certainly look more "primitive" than the Folsom-Yuman implement aggregates, and if no dates were available one would be tempted to ascribe them to an earlier period. This may, however, be due to cultural loss under the impact of a difficult environment. The rather surprising range of variation in the form of projectile points from different sites may also be referable to the presence of a sparse population living in small, widely separated bands, each of which had its own subculture within an impoverished Plateau pattern.

Evidence on the early occupation of the eastern United States is still scanty, but the whole Eastern Woodland area seems to have been occupied by 3,000-4,000 B.C. by simple cultures of Archaic type. Remains indicate a heavy dependence on wild vegetable foods, especially acorns and nuts, eking out by hunting and fishing. Fresh-water shellfish were important in the southeast, where a large proportion of the campsites are along rivers. Celts and other polished stone implements are common, and the culture level of these ancient Americans seems to have been very little below that of their North European contemporaries.

The origin of these eastern Archaic cultures can only be conjectured, but certain facts are suggestive. Although their flint-working technique was somewhat inferior to the best Folsom-Yuman, it was excellent, and the inventory of implement types was much larger than in the Plateau cultures. The presence of ground celts and adzes, completely lacking in the early Plains and Plateau cultures, is also highly suggestive. Although these implements conceivably might have been developed locally, as was the much later grooved axe, it seems more probable that they were introduced from Asia through either migration or diffusion. Since the main use of the axe is in tree-felling and that of the adze in large-scale woodworking, they belong with forest cultures. At a much later period, pottery of a northern Eurasian type also appears in the Eastern Woodlands, and the general similarity of northern woodland cultures in Eurasia and America has often been noted.

In historic times, the continuity of the Eurasian and American Woodland cultures was interrupted at Bering Strait by Eskimoid cultures adapted to Arctic littoral and barren ground conditions. If the carbon-14 dating is correct, the appearance of these cultures in the Bering Strait region was exceedingly late. Ipiutak, supposedly the oldest in the Eskimoid sequence, is dated at about A.D. 1000, on the rather unreliable evidence of uncharred wood samples.

However, the presence of wrought iron in Ipiutak deposits, and stylistic similarities of Ipiutak and Siberian art, make it improbable that the Ipiutak remains date from much before the beginning of the Christian era.

III

In view of these facts, I should like to suggest the following hypotheses: that the Bering Strait land bridge was not submerged until comparatively recent times, and that at some time after the migration of the big-game hunters, forests covered at least its southern side. With the strait closed and no southward flow of arctic water, such forests would imply only a slight rise in temperature in the Northern Hemisphere—a rise no greater than we know to have occurred two or three times since the last glacial retreat. If winds and currents were at all as they are at present, the Pacific Black Current would have warmed and moistened the southern side of the Bering Strait bridge, producing conditions not unlike those now found on the northwest coast. Moreover, a slight amelioration in the interior Alaskan and northern Canadian climates would have been enough to produce an unbroken belt of subarctic forest such as still stretches from Alaska to southern Labrador. Migrants with woodland-adapted cultures could follow such a forest belt from Alaska to the northeastern United States, bypassing the open plains to the south and making only marginal contacts with their big-game hunting population. Scattered finds in the eastern United States suggest that people with Folsom-Yuman culture had begun to penetrate the eastern forests before the migrants with Woodland culture arrived, but they do not seem to have settled the region in force.

The final submerge of the Bering Strait land bridge, with the consequent southward flow of arctic water, must have resulted in rapid climatic changes in the territories adjacent to the strait. Arctic conditions were established along the shores of the strait, and Eskimoid cultures moved in to fill the gap left by the withdrawal of forest-adapted tribes who could not cope with the new environment. Where these cultures originated is still an open question, but if they were introduced into arctic America from Asia no earlier than the beginnings of Ipiutak, they must have spread and diversified on the American continent with extraordinary rapidity. There is urgent need for definitive dating of some of the eastern American Eskimoid cultures, especially Dorset.

Diffusion of culture elements from Asia to America, and even sporadic migrations, probably

continued until fairly recent times, but after the breaking of the land bridge, these seem to have had little effect on the development of American culture. Thus the Nadene-speaking peoples, presumably the last migrants, have everywhere borrowed much more from their longer-established American neighbors than they have given. Moreover, as the northern Asiatics became increasingly well adapted to circumpolar conditions, the culture elements that could be diffused by them were of less and less potential utility beyond the limits of the circumpolar ecologies. With the development of agriculture, the cultural dependence of America on Asia came to an end.

As long as the Americans remained in a hunting, food-gathering economy, northern North America was culturally the most advanced part of the continent. None of the preagricultural cultures that have been found south of the Great Plains and Northern Woodland areas compares with those of these areas in richness of content. With the rise of agriculture-based civilizations in Middle America, the situation was reversed. The main line of diffusion was now from south to north, and Middle American influences become increasingly recognizable over the whole area east of the Rockies.

One of the most important contributions carbon-14 dating may be expected to make is that of establishing the relative ages and consequent relationships of American agricultural cultures. Even our present very limited data are suggestive. Thus the beginnings of the Archaic, the oldest unquestionably agricultural culture in the Mexican Highlands, seem to be set at about 1500 B.C. Maize of a very primitive type from Bat Cave, New Mexico, indicates agriculture there at about the same time. The lowest levels at Huaca Prieta in coastal Peru give the beginnings of agriculture there as about 2000 B.C. Maize does not appear in this region until about 500 B.C., a significant fact for those who ascribe a South American origin to it. All this suggests that agriculture was invented independently and more or less simultaneously in several different areas in the New World, a conclusion strengthened by the studies of Vavilov and others on the origins of American food plants.

Modern experience indicates the extreme ease and rapidity with which crops can be diffused from one agricultural area to another. American crops were being grown over most of the Old World within a hundred years after the discovery. I believe that a study of the diffusion of crops within America might hold the key to one of the most puzzling problems of American prehistory: why certain cultures developed with extraordinary

speed over short periods. Thus we know that the southwestern Basket Maker culture was transformed into full Pueblo within 200 years without any recognizable outside stimulus. The introduction of beans at the beginning of this period—supplying a protein deficiency and thus improving both the quantity and quality of the local food supply—may have been at least partly responsible. It seems conceivable that both the time and place of emergence of some of the American civilizations may have been determined by the assemblage, through diffusion, of aggregates of food plants which together provided an abundant and dietetically balanced food supply.

IV

Turning from such conjectures, the new dating has both reinforced certain earlier conclusions and disproved others. Thus carbon 14 seems to confirm the results of the tree-ring dating methods used in southwestern United States and to place the rise of full Pueblo culture at A.D. 850-950.

In contrast to this, Hopewell, one of the most advanced of the mound-building cultures of the upper Mississippi Valley, is now dated at about the

beginning of the Christian era. The most surprising reversal of earlier conclusions regarding the history of this region is that which places the Adena culture approximately 500 years later than Hopewell. It had generally been believed to be older than Hopewell and ancestral to the latter.

The general conclusion to be drawn from all these recent discoveries is that America really was a New World. The twin continents were not occupied until the cultures of Europe, Asia, and Africa were already hoary with age. Their civilizations did not emerge until thousands of years after the founding of the Old World cultures. The American civilizations, when they did develop, assumed forms curiously like and yet unlike anything elsewhere. They thus afford invaluable material for comparative studies. When we know their history, we shall have a better understanding of the processes of culture growth and change and will be in a better condition to control our own destiny.

References

1. ARNOLD, J. R., and LIBBY, W. F. *Radiocarbon Dates*. Chicago: Univ. Chicago Inst. for Nuclear Physics (1950); *Science*, 113, 111 (1951).
2. SOLECKI, R. *Sci. American*, 184, 11 (1951).



SEARCHLIGHTS

The colored searchlights overhead
Shift on the deep sky's softened bed,
Oblivious of the flare below
Where torrents of the people flow.
They point along the night, a thrust
Of ease, regardless of our trust,
Disdainful of the wheels that spin
Among the buildings' rising din.
They are the probing keys that knock
Upon the universe's lock.
They are the ones that all alone
Are searching while we build and drone.

DANIEL SMYTHE

Most Men Are Created Unequal

PAUL HORST

The author, who has been professor of psychology at the University of Washington since 1947, took his Ph.D. at the University of Chicago in 1931. He was assistant in the Research Division of the U. S. Civil Service Commission during 1930-32 and, later, supervisor of selection research in the Personnel Research Department of Procter & Gamble for ten years. His article is based on the address he gave as president of the Division of Evaluation and Measurement of the American Psychological Association at its September 1950 meeting at Pennsylvania State College.

IT IS A part of our great American tradition that one man is as good as another, if not a darn sight better. This point of view educators, politicians, and religious leaders have proclaimed for nearly two centuries. Since the time of Galton and Binet, however, a competing note has been struck. The burden of this note is, of course, that people do differ greatly from one another in many respects. The idea is not new to this century or even to this millennium. Plato in his *Republic* showed some knowledge of the phenomenon of individual differences and of its importance for the efficient operation of a political state. Some centuries later the most famous social philosopher of all time told a story about a man who divided his goods among his servants according to their differing abilities. Much earlier, a famous Jewish political and military leader used an aptitude test—strictly speaking, a performance test—as a basis for predicting individual differences in fighting ability. Coming down through the centuries, we arrive at a point in time when a great new nation was born and an ardent band of patriots declared, “We hold these truths to be self-evident, that all men are created equal.” There has been a great deal of variation through the years and among various groups of people as to the seriousness and literalness with which this declaration has been received.

I do not want to assume the unpopular role of a debunker of our great American traditions. It would be instructive, however, to recall briefly the historical setting in which the concept of equality of men received its greatest impetus. I do not pretend to be a historian, but I believe it is common knowledge to every high-school student that the hereditary monarchies of Europe were by their very nature such that the correlation between the social power possessed by rulers, and their competence to administer this power in socially adequate ways,

did not differ significantly from zero. It seems to me that the revolt of our forefathers was against systems of government that would allow power to fall into the hands of incompetent rulers. I question very seriously whether the mere fact of taxation without representation would have been enough to precipitate the Revolutionary War. If the decrees of George III had accorded with the interests of the American colonists, the course of history might have been much different. I believe this observation is no more blasphemous than to note that in this country it is only when people are unhappy about current conditions that they flock to the polls to turn out the political incumbents.

It was obvious to many of us in World War II that distinctions in authority and responsibility symbolized by rank were very necessary for efficient operation. I do not believe that the resentment that was exhibited toward differences in rank (and it is pointless to attempt to minimize this resentment) was due to unwillingness of subordinates to recognize differences in responsibility and authority. I think the resentment here was the same as that of our forefathers, namely, that in many cases there was a marked discrepancy between rank and the competence of the person holding the rank. Many enlisted men could have discharged the duties and responsibilities of many officers more competently than the officers themselves discharged them. What servicemen justifiably resented was not the fact that there was not equal opportunity for all in the Army, but rather that opportunity was not always commensurate with ability. True, much of the disparity was due to the gigantic task of mobilizing and organizing many millions of individuals into a complex military machine as efficiently and expeditiously as possible. But the unfortunate fact remains that some persons in positions of considerable responsibility in the military services still subscribe to the criterion of seniority as the most

satisfactory basis of promotion, and fail to recognize the significance of individual differences for the efficient operation of the armed services.

In developing his philosophy of the role of education in this country as a bulwark against Communist aggression, one of our leading educators insists that we strive to attain a classless society. As I understand it, this is a prominent feature of the Marxist philosophy. It seems pretty clear, however, that the Stalin regime early recognized how unrealistic and how psychologically unsound such a goal must be. Even the Soviets, with their artificial pressures and forces, soon realized that the phenomenon of individual differences could not be exiled to a Siberian prison camp. Our educational philosopher seems to regard a stratified society as the opposite of a classless society. This is a type of error that appears to be common to all human beings, including social philosophers. It is perhaps this tendency for human beings to categorize quantitative phenomena that is indirectly responsible for some of the resentment against the phenomenon of individual differences. We talk about the upper classes, the middle classes, and the lower classes, or, if we want a really fine breakdown, also the upper and the lower middle classes, so that we have five categories. I suppose the issue of a stratified society versus a classless society might never have become so acute if there had not been this insistence on drawing artificial and arbitrary cutoffs on the base line of distributions of individual differences.

Even leaders in the measurement of individual differences have committed this type of sin in specifying such categories as genius, normal, moron, etc., on the basis of whether a person happens to fall above or below an arbitrarily specified score. But the alternative to arbitrary categories is not the Procrustean bed of classless society. It is hard to see how in the long run any attempts to stretch the little people till they take the whole length of the bed and to cut off the limbs of the tall people so that they will not project over it can possibly lead to a better world. As I have indicated, I am sure the rebellion of our forefathers, the resentment of enlisted military personnel, and the antagonism of the great majority of our American citizenry today toward people in positions of authority and power derive not from resentment at being placed below someone in some scale or other but from the feeling, right or wrong, that the people placed in such positions do not have the ability commensurate with the authority.

Why should we try to ignore or minimize the virtues of those who are superior to us, or the weaknesses of those who are inferior? We all know

people who are superior to us in a great many respects, and no philosophy of equality or of a classless society—nothing we can do or say—will make them less superior. Why should they pretend that they are not superior in those respects in which they excel? Likewise, why should we deny that we are superior in many ways to many people, or why should they resent our superiority? It seems to me that efforts to insist on a classless society can result only in encouraging the demagogues who, under the guise of equality for all, establish police dictatorships in one country after another.

The Ideal Social Structure

People do differ, then, and these differences are extremely important when it comes to drafting a plan for an ideal social structure including its educational, political, and economic aspects. It is primarily those individual variations which differentiate people according to the effectiveness with which they react to their physical or social environments that concern the measurement psychologists. We are concerned with measuring individual differences in socially significant behavior, and I would say that the behavior that is rewarded or penalized by society is socially significant.

Why should the measurement and evaluation psychologist be concerned with the measurement of individual differences for socially significant kinds of behavior? The reason issues from an axiom which I hold to be more nearly self-evident than "all men are created equal." This axiom is quite simply that in general what a person receives from his fellow-men, when appropriately quantified, should be a monotonically increasing function of what he contributes to his fellow-men. Fundamentally, it is the old-fashioned idea of an honest day's pay for an honest day's work. By and large over a lifetime it seems reasonable that people should get out of this world about what they put into it. I am not concerned here with ethical or moral considerations. What I am saying is that, if adequate psychophysical means were devised for evaluating a person's contributions to, and requisitions from, society and the one plotted against the other, the points should define a curve whose derivative was at every point greater than zero.

If we are willing to grant that a relationship of this type between contribution and requisition is the ideal to be striven for, then we have the difficult problem not only of scaling the activities within a given type of social activity category but also the more difficult problem of equating the social value scales for one category of activity with another. It is the practical difficulties involved in attempts

to develop scales of this kind that have led many people to throw up their hands and insist that it is meaningless to talk about the relative values of various types of human activity to society, and to insist on the futility of trying to measure what people get out of life.

Assuming that quantification is possible in this domain, let us not confuse the kind of rewards that consist of goods and services with those that are of a more abstract and emotional character. Consider, for example, the satisfaction that comes from achievement, the pride in a job well done, the adulation of one's neighbors or fellow-men. Consider also the rewards that are in the nature of promises—of a much better life in the future, or of land reforms, or of rule of the proletariat, or of a life of bliss and happiness in the world hereafter (even though in this life we sow that another may reap). Powerful and unscrupulous men in all ages, whether ecclesiastical, political, industrial, or what not, have capitalized on this type of reward to exploit the masses.

This is all by way of saying that an ideal social philosophy which takes account of individual differences in ability to contribute goods and services to society must also insist that the rewards be in kind. If we do not insist on this point of view we open the way, as indeed it has been opened in the past, to all manner of demagogues, whether they wear the cloak of the cleric, the robes of the monarch, the uniform of the soldier, or the plain suit of the businessman. This philosophy of payment in kind has been objected to by persons who point out that emotional and abstract rewards may be just as real and satisfying (if not much more so) as the more concrete rewards represented by conventional goods and services for which we pay our hard-earned money. I do not mean to say that such rewards have no place in our society; I am all for teaching people to enjoy work for the sake of personal achievement, to strive for the approbation of their fellow-men, to gain satisfaction in the knowledge that a better world awaits their honest efforts. But I do want to urge strongly that rewards of this type should not be acceptable as legal tender for genuine social contributions. Not only is this point of view important in order to keep demagogic aspirants and false leaders from counterfeiting social rewards in order to achieve power, but also to keep the inventories in the social warehouse at the maximum level.

To simplify subsequent reference let us call the theory of positive relationship between contribution and requisition merely the "positive slope theory." Hardly anyone will say outright, "No, I don't be-

lieve in this theory of a social state; I believe everyone is entitled to get as much in the way of goods and services out of this world as he can get away with, regardless of what his contribution might be." Most people will not make a statement as blunt as this, yet many will hesitate to subscribe whole-heartedly to the positive slope theory. Many of us secretly hope that luck will be in our favor and give us a little more than we really deserve. We have a hidden fear that, if there really were accurate means for measuring just what we requisitioned from the social contributions of others, and if there were something like a one-to-one relationship between the two, strictly enforced, then we might not get quite as much as we would otherwise.

I have not come to this conclusion hastily. I have observed for a good many years and in many different situations that people resent being evaluated with respect to socially significant activities. Take, for example, the use of employee-rating plans in industry. No matter how fair they are, they will always be criticized by influential elements in the particular social group concerned. Attempts to sell any system, no matter how reasonable, to teachers whose increase in rank or salary depends on ratings offer the same problems. The history of efficiency-rating procedures in the United States civil service records the stumbling blocks put in the way of the acceptance of any system. Efforts to establish several competing kinds of proficiency-rating plans in the military services both during and since the war provide an interesting commentary on resistance to precise personal evaluation.

There may of course be other interpretations of the opposition to systematic and formal evaluation instruments and techniques, but I think my interpretation is further supported if we observe that this phenomenon is closely related to the gambling tendencies of a large portion of the human race. Games of chance seem to have a basic human appeal. Mankind through the centuries has developed all sorts of formal procedures whereby one may risk a little to gain a lot. Recent developments in our large cities call attention to that widespread powerful and elemental psychological mechanism which is the motivation to gamble. It seems necessary to make something of an issue of this rather basic reliance on chance rather than on skill, because this tendency cannot be ignored in the design of an ideal social structure. The tendency is a most vital factor in our society and, so far as I can see, it is 100 per cent antithetical to the positive slope theory.

At the present time I am not satisfied with my own disposition of this phenomenon relative to the

role of individual differences in an ideal social state. As a temporary improvisation, however, I am willing to say that, ideally, gambling should be regarded as a leisure-time activity in a rather narrow sense of the word, and that it should not be permitted to conflict with the positive slope hypothesis in an ideal social structure. I am not much impressed by the inevitable retort that you can't legislate human nature, for the evolution of civilized society has consisted in large part of the legislation and regimentation of human nature. This is not to say, of course, that human nature has taken it lying down or that in the future it will do so, but nevertheless, whether grudgingly, beligerently, or with alacrity, society has accepted increasing regimentation and must continue to do so as its structure becomes more complex.

The gambling instinct is one rather evident obstacle to the positive slope hypothesis, and if I did not believe so strongly in the hypothesis and its basic soundness for an ideal society, this all-too-human propensity would lead me to question its validity. I believe, however, that the difficulties inherent in any proposal for an ideal social state must be made explicit. And one encounters other problems in the positive slope theory. For example, should a person in an ideal society be permitted to exercise discretion as to the conditions under which he contributes either goods or services? Should he be allowed to give money, material goods, or his own skills to whomever he pleases under whatever conditions he pleases? In particular, should he be allowed discretion to convey his goods and services to other persons without reward or payment in kind? Our theory would indicate that he may not. If complete freedom of choice is given, then we open the way for unscrupulous political, ecclesiastical, or social organizations to employ techniques to influence people to part with their goods and services without appropriate compensation. In general, it would seem unsound to have no controls whatever on the rules by which a person may convey his goods or property. Shall we go to the other extreme and say that he may convey them only if he receives an equal amount of goods and services? Note here that the transfers would not necessarily be reciprocal. Usually, in a complex society they will not.

The family as an organic unit makes the positive slope principle difficult to apply. What shall be the contribution of the wife in exchange for food, clothing, shelter, entertainment, and what not provided by the husband? It seems quite natural to define bearing and caring for children as a social contribution, for without such there would be no

society. But what about childless couples? What about homes well equipped with servants, so that the wife has nothing but leisure activities to engage in? The tendency for many married women, after maternal responsibilities have subsided, to get a job or to take on part-time work seems to be increasingly the vogue. I would say, then, that the trend is to recognize the responsibility of women to make socially significant contributions somewhat commensurate with their requisitions from society. But, even at that, the concept of the lady of leisure does not at present carry with it the opprobrium which the positive slope theory would attach to it. I suspect that in the ideal social state ladies of leisure must become obsolete.

But, even assuming that this species is gradually disappearing, certain theoretical obstacles persist. It is easy to argue that the president of a corporation might contribute enough to the social structure to entitle him to requisition from it a \$50,000 yacht; it is easy to question whether the man who shines the president's shoes contributes enough to justify the requisitioning of a \$50,000 yacht. It may be a little more difficult to argue that the wife of the industrialist contributes enough to society to justify her participation in the pleasures of a \$50,000 yacht while the wife of the bootblack is denied them. So far I have no good rationalization for letting Mrs. President enjoy the yacht while denying this pleasure to Mrs. Bootblack. One could argue, of course, that because of the tendency toward selective mating Mrs. President could be expected to have the capacity for making a greater social contribution indirectly, through the achievements of her husband, than does Mrs. Bootblack through hers. But I am not convinced by this reasoning. One could argue that husband and wife are a single socially organic unit, and that the twain shall be one flesh until death do them part. Perhaps a somewhat better case could be made for this point of view.

But we get into still more trouble when we consider the children of the family. First, we encounter the problem created by inheritances. To what extent should a parent in an ideal social state be allowed to pass on to his children goods and privileges that he has accumulated? Property, including money, which is a form of communication specifying the amount of property one is entitled to requisition, does bestow social power and control upon individuals. The father who passes an inheritance on to his son passes with it social power and control. I have had students argue that a parent should have the right to pass on to his offspring the goods he has accumulated because this

may be to the parent the highest possible reward for his lifetime of effort, and that to deprive the parent of the satisfaction of passing his goods on to his children would be a great injustice. I have already pointed out that the rewards for socially significant activity should be in kind. It seems to me this alone is reason enough why the argument of satisfaction to the parent is not adequate justification for passing his goods on to his children. But a more potent argument is the fact that in so doing the parent bestows power upon the heir. Should power or social control be bestowed upon children merely on the basis of the parents' economic status, or should this power be commensurate with the offspring's ability to make socially significant contributions?

Inheritances as such, then, are not in accord with the positive slope theory. The trend of our inheritance tax laws recognizes the fact that the socially useful abilities of children may not correlate significantly with the economic status of parents, but this is not to say that what they recognize is the positive slope theory. The inheritance tax trend is more in line with the Procrustean bed theory than the positive slope theory.

The problem becomes a little more complicated when we consider the early requisitions from the parents by the children. We may, perhaps, regard husband and wife as a single, organic, psychological unit and avoid the serious logical dilemma posed by children. It is only during their socially non-productive period that children may be regarded as a part of a single organic family unit, for after they are grown and take their own position in society they must be looked upon as distinct units. Let us assume that society should provide life-preparatory opportunities for children according to some rule or other, whether it be for the purpose of equalizing adult abilities or whether it be concerned with providing opportunities commensurate with potential value to society. How would you prevent well-to-do parents from engaging the best private tutors, and from bestowing all sorts of cultural advantages upon their children which the poorer classes cannot afford?

Children of well-to-do parents, even though their potentialities to contribute constructively to society may be less than those of some economically handicapped families, nevertheless are bound to have greater opportunities under our present system. It is of little help for the development of a theoretical framework to point out that frequently the so-called opportunities of children in well-to-do families actually have a softening effect upon them, and do not prepare them as well to compete in life

situations as do the struggles of those whose families are less able to requisition from the social warehouse. And even though police states have taken over much of what was formerly the parental jurisdiction of children and have demonstrated that it is possible greatly to reduce or minimize the influence of differences in home life and background, we should indeed seek far for other solutions to the problem before accepting these.

It may of course be that, with the sharply graduated income tax system, and a greater expenditure of tax money on better schools, better teachers, more parks, playgrounds, museums, and libraries, and other free cultural and educational opportunities for children, the disparity between the effective opportunities which the various economic classes can provide their children will continue to shrink. This may actually be the solution that is under way at present. We can see, then, that the positive slope theory has some inherent difficulties because of the role of the family in our culture as an organic social unit. It is the temporary character of this role that causes the trouble, for it is only after the unit breaks up that the children become, in any appreciable sense, contributors to society. At that time, however, the life-preparatory activities have already drawn upon the social warehouse in some fashion, whether in conformity with an acceptable social philosophy or not.

Another fundamental difficulty with the positive slope theory, which it is only fair to emphasize, is concerned with the quantification of social contributions and withdrawals. Presumably psychophysical scaling techniques can be worked out or adapted from those already available, for quantifying the values of goods and services over rather wide areas. But the value of a specifically defined kind of socially useful activity may vary widely for individuals or groups of individuals over a period of time, so that we have temporal variation in the value of a social contribution both among individuals and for a given individual. This phenomenon greatly complicates the implementation of a positive slope philosophy, but I do not think that it is inherently inconsistent with the theory. We might regard one kind of socially useful activity as that which provides the shifting evaluation of goods and services. Here, of course, we refer to all sorts of buying and selling activities for purposes other than direct consumption. In fact, many argue that a free market in which supply and demand determine the relative value of various goods and services is the most practical kind that can be devised for quantifying their shifting social values. The evils of an uncontrolled system in which

private operators may artificially influence the direction and extent of price variation have long been recognized, however. Many of the safeguards provided by legislators for those who buy and sell for investment and speculation indicate an acknowledgment of the need for systematic control over the temporal variation of prices. Nevertheless, the systematic controls exerted by the government may be just as arbitrary as those of private individuals manipulating the price structure for their own advantage.

It is certainly imperative that, in the ideal social state, completely adequate operational definitions of the social values of goods and services be clearly formulated. The economic disaster of 1929 showed that an uncontrolled market was in no sense adequate to insure that anything remotely resembling a positive slope system would operate automatically.

Quite clearly, if some people requisition more than they contribute, then others must contribute more than they requisition. If only a few people requisition a great deal more than they contribute, so that a great many people contribute only a little more than they requisition, then we call the excess requisitioners brilliant financiers and set them on pedestals and hail them as elder statesmen. One such operator who has been extremely successful in stock market operations has pointed out publicly that his success is based on the fact that he has done just what people wanted him to do. When people were extremely anxious to buy industrial securities, he would sell to them, and when they were extremely anxious to sell, he would buy from them; so by doing what his fellow-citizens insisted that he do he became wealthy. I point out this particular example because it shows the dangers of accepting uncritically the evaluation mechanism of uncontrolled market buying and selling, and of assuming that people should be given unlimited discretion as to the values they place on goods and services. It is hard to make a good case for the social value of buying and selling for purposes other than for processing, consumption, or to make goods more readily accessible to potential consumers.

Evaluation and Measurement in Public Service

I have discussed the importance of individual differences in socially significant activities, of the role to be played by a theory of a monotonically increasing function between contribution and requisition, of the importance of measuring contribution and requisition accurately, and of the difficulties involved in accurate measurement in this area. Let us consider, finally, how evaluation and measurement

might operate in the public service field, where we have been most prone to take for granted the dictum that all men are created equal. Should all men have an equal right to vote? Is voting a right or a responsibility? Certainly we have all had the experience of going to the polls and seeing on the election ballot the names of people we had never heard of, who were candidates for offices we didn't know existed. The question may well be raised whether we have either the right or the responsibility to vote for unknown candidates for unknown offices. Presumably, if the offices are important, and the functions are important to the local community, then it is essential that they be filled by qualified individuals. Certainly the way to get them filled by qualified individuals is not by any form of lottery system.

I have taken the extreme case of voting for minor local officials, but it seems to me the same principle applies to all elective offices. How much do you and I or the average citizen know about the particular qualifications and abilities required of the ideal governor of our state? How much do we know about the extent to which competing political candidates actually have these qualifications? As a matter of fact, how much does the average voter know about the abilities required of an effective President of the United States, and how much does he know about the extent to which political candidates possess these qualifications? Other things being equal, shouldn't the person who knows a great deal about the job requirements of a political office and the job qualifications of the various political candidates for that office have more to say in the selection of the official than the person who knows nothing about the qualifications of the candidate or the requirements of the job? If we grant this, we clearly imply that there should be a set of examinations to test knowledge of job requirements and knowledge of the qualifications of candidates. To keep the system relatively simple, one might have a qualifying score, with only those above the score entitled to vote on a particular candidate.

There is, of course, another approach to the selection of public servants, exemplified by the civil service system. The question may well be raised as to what kinds of public service jobs should be filled by means of elections and what kind by means of civil service examinations. Current practice implies that people should be required to demonstrate qualifications for the job only if the job is unimportant. If the job is of extremely great importance, then it becomes less necessary that the candidate be required to demonstrate his qualifications for it,

whereupon Lady Luck exercises greater control.

It seems to me that one of two methods, or a combination of both, is available for exploiting the phenomenon of individual differences for the improvement of government. An obvious step would be to extend the civil service system to include more and more elective offices. Indeed, why should not our United States congressmen and senators be required to demonstrate their selective proficiencies in science, economics, sociology, political science, and other fields of knowledge relevant to intelligent legislation? As a matter of fact, it might not be too much to ask that a candidate for the presidency of the United States have some knowledge of the forces that influence the state of health of our national structure and that he be called upon to demonstrate at least a bare minimum of such proficiency.

We could, then, directly approach the problem of an improved governmental structure by insisting that relevant individual differences be measured and only the most competent be selected for office. If this method were carried to the limit, it would mean that all public offices would be filled from civil service examination rosters, and that elections would become a thing of the past. Apart from the theoretical difficulties involved, the sentimental and emotional barriers to the elimination of the voting system would probably be insurmountable. Another alternative would be somewhat arbitrarily to define, as we do now, the jobs to be filled by examination and those to be filled by election, but to capitalize on individual differences among the voters to be sure that only the most competent to vote would be permitted to do so. In the first case, the candidates would take the examinations, and, in the second, the voters would take them, allowing the candidates to establish their candidacy very much as at present.

Of course, if we really took individual differences seriously, and we wanted to make the most of them to ensure topnotch public service personnel, we could combine the two systems. In this case, the candidates would have to pass qualifying examinations before being allowed to run for offices, and the electorate would have to pass appropriate examinations before being allowed to vote for candidates.

Aside from the sentimental objection that all men are created equal, there are at least two fundamental difficulties involved in a recognition of individual differences in the political area. The first is a question of who would prepare the examinations. I mention this objection first because it is the one most frequently raised against a proposal of this kind. Until the time seems ripe for a definitive answer to the question, I would prefer to answer it with further questions. For example, who prepares the examinations for our present civil service positions, both Federal and local? Is the problem of extending civil service examinations to positions of greater responsibility any different in principle than the present civil service examination system? Who qualifies the candidates for our primary system at the present time? Would it not be feasible to establish examination commissions by means of rationales which would be at least as acceptable as those on which our current political machines operate, once people got used to the idea? Presumably some sort of ultimate examination commission would have to be established, whose members were as competent, objective, and incorruptible as the members of the United States Supreme Court are supposed to be.

A somewhat greater theoretical difficulty that I envisage with any system requiring qualifying examinations for the electorate is based on the assumption that what would be best in the long run for the qualified electorate would also be best for those who do not qualify. A system of qualified electors would involve at least two important basic assumptions: first that the electors would know how to vote, not only for their own best interests, but also for the best interests of their less competent fellow-citizens; second, in the light of what would be best for the country as a whole, that guarantees could be incorporated into the system to see that the electors voted for the benefit of all. Such guarantees would be difficult, but I think not impossible to establish.

In conclusion, I shall admit freely that there are many obstacles to the achievement of a social system that rewards its members according to their contributions and utilizes fully the phenomenon of individual differences for the benefit of all. Nevertheless, I believe the highest goal that measurement and evaluation psychologists can strive for is the development of those instruments and techniques required by a society which aspires to capitalize to the fullest upon the fact that most men are created unequal.

Origin of the Sweet Potato and Primitive Storage Practices*

J. S. COOLEY

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HOW the sweet potato (*Ipomoea batatas*), with its highly palatable and nutritious fleshy roots, has evolved within the convolvulus family is still veiled in mystery; certainly it was long before any written records existed. But the importance and unique characteristics of this food plant justify an effort to put together the fragments of early records and other evidence, and to draw what deductions may be possible regarding its probable origin and dissemination.

In prehistoric times the sweet potato was used for food in two widely separated regions of the world, the tropical Americas and some of the islands of the Pacific. There is no evidence, however, that it was used by the primitive people of Europe, Asia, Africa, or Australia. Nor was it known to the ancient civilizations of Egypt, China, Babylon, Persia, India, Greece, or Rome. One cannot be sure how long this plant has been used for food. The peoples of tropical Latin America were probably using it many years before the arrival of the Spanish explorers. Columbus found the natives of Cuba using the sweet potato, and later Spanish explorers found it in Mexico and South America.¹ No record has been found of the cultivation of the sweet potato by the Indians in pre-Columbian times in the area that is now the

United States. Some of the Indian tribes in the western part of this country, however, roasted and ate the roots of a wild plant known as "big root" (*I. leptophylla* Torr.). Since these roots were not especially palatable they were eaten only when the Indians were hard-pressed by hunger. The South-eastern tribes of Indians did not cultivate the sweet potato until after its introduction by the white settlers. They did, however, use the roots of the wild convolvulus, *I. pandurata*, for food. This root, which sometimes weighs as much as 20 pounds, is popularly known as "man-of-the-earth."

It is possible that the sweet potato was carried into temperate regions of America by the Mayan Indians or by those making contact with them on trading expeditions. Sweet potatoes were grown by Virginia colonists as early as 1648,² only forty years after the establishment of the Jamestown settlement. The early use of the sweet potato by the colonists is an indication either that they had ready access to the West Indies, or that they had obtained the vegetable from the Indians.

During the Spanish explorations, probably prior to 1526, the sweet potato was introduced into Spain and thence into other European countries (Oviedo, as quoted by De Candolle,³ p. 55). The plant was known in Europe by the Indian names of *batata* and *padada*.¹ The English word "potato" was derived from this source. The sweet potato was introduced into Europe possibly sixty or more years before the Irish potato (*Solanum tuberosum*) and was known there as the "potato." Confusion arose, however, when what is now called the potato (the

* This article was read during its preparation by H. W. Krieger, anthropologist, Smithsonian Institution, Irving Rouse, anthropologist, Yale University, and George Carter, geographer, The Johns Hopkins University. Their suggestions have been very helpful, and it is a pleasure to acknowledge them.

Irish, or white, potato) was introduced under the same name. It is known that the white potato was grown in Europe as early as 1588. This knowledge is based on records left by a famous botanist, Caroleus Clusius. Soon after the white potato was carried to England it became known as the Irish potato, the sweet potato still being known as the potato. Later the sweet potato was designated Spanish potato or sweet potato.

Scholars endeavoring to trace the origin of this plant have placed considerable emphasis on a study of the wild species in various parts of the world. No single wild species has been found that is definitely known to be the plant from which the sweet potato is derived, however. Botanists classify the present-day sweet potato as belonging to the convolvulus family, to which the morning-glories and the giant bindweed also belong. Most of the known wild species of the genus *Ipomoea* differ greatly from present-day cultivated sweet potatoes.

Many of the botanists who have made a study of wild sweet potato species believe that *I. tiliacea* (Wild) Choisy is the most closely related wild species from which the cultivated sweet potato may have arisen. This plant grows in tropical America, in the islands of the Caribbean Sea, in the West Indies, and in Florida. It is a twining plant, with stems 7 feet or more long, sometimes tuberous roots, and ovate leaves 3-4 inches long. The flowers, which are 3-4 inches long, are purple-pink or nearly white, usually with a dark eye.† This wild species is not known to be native in any regions other than tropical America and adjacent islands.

Convolvulaceous plants belonging to the genus *Ipomoea* are widely distributed over the world, particularly in tropical areas. Unlike the sweet potato, however, most of these plants do not have a fleshy storage root, and the roots of those species that do are often most unpalatable, or even violently purgative. One cannot help marveling at the fact that such a splendid food as our sweet potato seems to have evolved from such unpromising sources as the wild convolvulaceous plants.

Recent studies of King and Bamford⁴ show that most of the species and varieties of *Ipomoea* investi-

† The most conspicuous differences in *I. tiliacea* and *I. batatas* may be seen by the following comparisons: *I. tiliacea*: sepals 8-10 mm long; stems usually pilose or pubescent and twining; leaves simple or angularly lobed; roots sometimes tuberous. *I. batatas*: sepals 10-14 mm long; stems usually glabrous and prostrate; leaves simple or variously divided; roots tuberous. These characteristics do not always hold, for many forms or strains of sweet potatoes have pubescent stems, and some are upright, not prostrate, in habit of growth.

tigated are diploids, with the basic chromosome number 15. The two known exceptions are *I. ramoni*, a tetraploid with 60 chromosomes (4 sets) in vegetative cells, and *I. batatas*, a hexaploid with 6 sets, or 90 chromosomes. Theoretically a tetraploid form might have arisen from a diploid through mutational chromosome doubling; and crossing of a diploid and a tetraploid might have given rise to a triploid, which through chromosome doubling would produce a hexaploid type. Interspecific hybrids of *Ipomoea* must be difficult to make, however,—at least under some conditions—for in the course of King and Bamford's work, which extended over three growing seasons, more than 500 interspecific and intervarietal pollinations in this genus were made, but none was successful. The complex cytological make-up of the sweet potato suggests considerable complexity of origin. Further cytogenetic studies need to be made of the present-day wild plants showing some similarity to the cultivated sweet potato. Such a study may reveal some important relationships that will throw light on the origin of this important food plant. The usual conclusion to be drawn from the available information is that the sweet potato originated from wild plants growing in tropical America and that this stock was carried to other parts of the world, where it was subsequently grown.

Undoubtedly the present-day sweet potato has undergone many and radical changes during the years in which it has been cultivated and used for human food. Variations in plants may arise both from genetic variation in seedlings and from sports, and mutations are of frequent occurrence in the present-day sweet potato. Sufficient variation may take place even in the vegetatively propagated sweet potato to develop distinct new varieties. To cite an example, some years ago, Thomas White, of the Maryland Agricultural Experiment Station, had brought to his attention, in a field of Big Stem Jersey, one sweet potato having flesh of a deep, rich, golden color in contrast to the creamy yellow of the rest of the crop. This specimen was saved and used for propagation purposes, and from this start the commercial variety Maryland Golden has arisen.

The people of a temperate climate usually think of the sweet potato as not blooming or setting seed, but in some tropical regions—for example, in Puerto Rico, where this plant has been grown for centuries—it often blooms and sets seed. And some varieties or selections will bloom and set seed in temperate regions. Where natural reproduction takes place by seed, widely different types

of plants may arise as the result of genetic variation which is due to natural hybridization of unlike parents. All known forms of sweet potatoes are extremely heterozygous, their seedlings representing a remarkable diversity from their parents. From chance seedlings, which may be quite different genetically, some outstandingly good plants may have been noted and saved for propagation. It is easy, therefore, to postulate that radical changes may have taken place in the sweet potato during sexual as well as during asexual reproduction.

In the early literature dealing with the sweet potato it is sometimes difficult to determine whether the reference is to the true yam (*Dioscorea alata* or other species) or to the sweet potato. The yam differs markedly from the sweet potato. It has slender twining stems, often measuring as much as 20 feet in length. This plant has underground tubers that vary from the size range of white potatoes to enormous yams weighing 30 or 40 pounds and measuring as much as 3 feet in length. In this country "moist-fleshed" sweet potatoes are often erroneously called yams.

A glance at the history of two of the early civilizations in America will throw some light on the origin and antiquity of the sweet potato. In the dim ages of the past there flourished two highly developed civilizations in tropical America: one in Middle America, the Mayan; the other in South America, the Peruvian. The Mayans are a very ancient people. Morley⁵ states that pre-Mayan history extends as far back as 3000 B.C. In some of the later epochs the Mayans evolved a highly developed system of agriculture. They had a number of distinct varieties of maize, which was their main crop, and they also cultivated the sweet potato. The Peruvian civilization, which arose in the Andean highlands, also developed in very ancient times an advanced type of agriculture. Here also maize played an important role and the sweet potato was cultivated.⁶

Recent archaeological studies in South America provide evidence that man's occupation of that region goes back into prehistoric times. Junius Bird,⁷ in his report on excavations in the Huaca Prieta in Peru, concludes that this region gives the earliest record of a farming and fishing community in the Americas. As a guess he places a date on the occupation of this region at possibly as early as 3000 B.C.

The length of the period during which man has lived in the Americas is much greater than was at one time supposed. Recent archaeological excavations in Mexico by De Terra⁸ have uncovered a skull and other parts of a human skeleton

(Tepexpan man) in a stratum to which a date of 9000 or 11,000 B.C. is assigned. Carter⁹ reports archaeological studies in a valley in California indicating man's presence in that region as long as 100,000 years ago.

In pre-Columbian times while the sweet potato was fulfilling an important function in the economy of the people of tropical America it was also an important food plant for the Maori of New Zealand. Some anthropologists^{10, 11} are convinced that the sweet potato was grown in New Zealand long before the beginning of the Spanish explorations.

Extensive anthropological studies on the Maoris, the early inhabitants of New Zealand, disclose some interesting and valuable facts concerning the importance of the sweet-potato plant and the intimate way in which it was interwoven with the life of the people. Since they grew no grain the sweet potato became the main food crop. They called it *kumara*. The origin of the *kumara*, insofar as this primitive people is concerned, is closely connected with their mythology. The importance of this plant as food probably accounts for their giving religious significance to its origin and also for the elaborate ceremonies connected with planting, cultivating, digging, and storing it. Such ceremonies are often associated with the principal food crops of primitive agricultural peoples the world over. The North American Indians carried out elaborate ceremonies with corn, and in the mythology of many peoples certain gods and goddesses are looked upon as the tutelary or protecting spirits for cultivated products. The ceremonies of the Maoris began at planting time, when whole roots were planted directly in the field. Much of the work was done in unison with a song or chant of the priestly adept or chief. At important operations in the growing, digging, and storing of the crop certain other ceremonies were performed; and at the conclusion of the digging and storing there was a great feast. In one of the smaller feasts, Colenso¹² says they used 2,000 bushel baskets of sweet potatoes.

There is evidence that the sweet potato was introduced into New Zealand from some of the Polynesian Islands at a very early date. One writer¹³ states that it was brought there four or five generations before A.D. 1350. There is a tradition that the Maoris, not finding the *kumara* on their arrival in the country, sent an expedition back to their old home in the Pacific Islands to secure a supply for seed purposes. This expedition probably brought back a wide range of varieties. Colenso¹²

states that no fewer than 30 varieties have come to his attention, all with separate names and very divergent characters. The sweet potato sometimes blooms in New Zealand but is not known to set seed there; hence, new varieties probably arose as sports. Even though the Maoris used crude wooden tools, they developed relatively advanced methods of culture. They planted whole roots directly in the field—i.e., no plant bed was used—and they planted in raised hills. Where the land was not right according to their ideas, they carried baskets of sand or gravel to make it more suitable. This material was often piled around the plants to a depth of 3 or 4 inches, at an enormous expenditure of effort. In one region alone more than 200 acres were artificially covered with gravel.

It appears probable that the sweet potato was being cultivated and used for food in two widely separated regions of the world before communication was known to exist between these regions. The idea first prevailed that the Spanish explorations and conquests were responsible for the introduction of the sweet potato into Oceania, where it was subsequently highly prized and disseminated. When it became known, however, that the sweet potato had been used in New Zealand many years before the Spanish expeditions in America, it was necessary to postulate some other method of transporting it from South America to Oceania. It is generally conceded that man has been the chief agent in the dissemination of cultivated plants, and Carter¹⁴ emphasizes the importance of man in the carrying of cultivated plants across large bodies of water. He also emphasizes the fact that plants became markers of the ramblings of man.

Hornell¹⁵ has made a special study of the various possible ways in which the sweet potato could have been taken from the west coast of South America to Oceania. This study included the type of rafts used by the Polynesians and an analysis of the ocean currents that would aid in getting a craft from Polynesia to the west coast of South America and thence back to Polynesia. From the tenth to the fourteenth centuries the daring and adventurous Polynesians made long and hazardous trips over the Pacific Ocean. Voyages were made between Hawaii and Tahiti, probably via the Marquesas and the Fanning Islands. These voyages must have involved distances of more than 2,400 miles, with probably only the seasonal flight of migratory birds as a guide.¹⁶ The distance from Easter Island, the last land on the route from New Zealand to the west coast of South America, is 2,200 nautical miles. Hornell believes that the trip

from Polynesia to South America could have been made by taking a southern course and finally following the Peruvian Current up the coast of South America. The distance one way would not be greater than 2,500 miles, and it is known that trips as long as that were made by the Polynesians. More difficult still would be the return voyage, since that would involve reaching a particular tiny island. The return could have been accomplished by going northwest from Peru, getting into the equatorial current, and making a landfall on the Marquesas Islands. From these, the travelers could easily sail from one island to another. It was a common practice among the Polynesians to carry food, plants, animals, and in some cases women, on their long dangerous voyages so that if they were cast ashore on an uninhabited island they would be able to maintain themselves there.

Whether the sweet potato was developed in the tropical regions of America and transported to the Polynesian country in very early times, or whether it was developed in Polynesia and carried by the Polynesians to America, is still a subject for speculation. It is usually assumed that the sweet potato is of American origin.

When the Spanish explorations took place the sweet potato that was then known in tropical America was introduced into the Philippines, as well as into other Spanish possessions.

The sweet potato was not taken to China until within historical times. The investigations of Laufer¹⁷ give us the interesting and graphic story of how the sweet potato reached China and Japan. In 1593 the province of Fukien in southern China, presumably because of the ravages of a typhoon, was stricken by famine. The governor of the province, Kin-Hio-tseng, sent a commission to Luzon in the Philippines in search of food plants that might relieve the pitiful plight of his people. After many adventures in Luzon the commission secured some seed stock roots of the sweet potato, and in 1594 it returned home with this novel plant. The new plant was greeted with unbounded joy. Although the economic value and the high nutritive properties of the newcomer were at once recognized, it was not until 1786 that an imperial order was issued to encourage the cultivation of the sweet potato as a means of preventing famine.

There are several different accounts of the movement of the sweet potato from China to Japan. Laufer¹⁷ reports that about fifteen years after its introduction into Fukien the sweet potato was transported to Formosa, and to the Luchu Islands as early as 1605. At that time, the

Luchuans still formed a kingdom of their own, although recognizing the sovereignty of the Chinese emperor. Nugun, the superintendent of the Chinese settlement in Napa, the chief town of the archipelago, presented a native village chief, Masatsune, with cuttings of the plant. He eagerly studied its cultivation and promoted it in his country. A memorial pillar has been erected in front of Nugun's tomb, and he is canonized under the name *Mmuushume*, that is, "Ancestor of the Tuber." A Japanese farmer, Maeda Riuemon, a native of the province of Satsuma, made the acquaintance of the sweet potato while paying a visit to Luchu in the latter part of the seventeenth century. On his return home he introduced its cultivation into Satsuma, and from there it spread over the northern provinces of Japan. Riuemon's tomb is known as *Kara-imo-den* ("Temple of the Sweet Potato"), and there every spring and autumn the soul of this simple farmer receives offerings from his grateful countrymen.

The word used for the sweet potato in different parts of the world has been the object of much interest and study by certain ethnologists. Christian,¹⁸ who has made a special study of the words used in Polynesia and other parts of the world and compared them with some basic Sanskrit words, says:

The various Polynesian forms, *humara*, *kumala*, *umara*, *umala*, *uara*, *uala* and *uwala*, for the sweet potato, form a curious chain of evidence. In the Northern Philippines they call it *kamote*. . . . Cf. Malay *barat* and Sanscrit *Barata* (S. India). . . . With *Kumala* compare Sanscrit *kauwal*, the lotus, *Kumthla* and *kumad* and *kumud*, the white esculent lotus (*Nymphaea esculenta*), also Sanscrit *kalma*, a *lotus*. The Quichuan (Peruvian) word for sweet potato is *kumara*. The similarity of the Peruvian and Polynesian words for sweet potato may be important in tracing the origin of this plant. The question arises as to whether the *kumara* was brought from India to South America by pre-Columbian navigators.

History of Curing and Storing

No storage problem existed when the sweet potato was growing in its native tropical habitat—the potatoes were dug as needed. However, after this plant was taken to a country having a temperate climate, such as New Zealand, it was necessary to keep the edible part, the fleshy root, alive and sound throughout the winter in order to have it available as winter food and to grow more plants the next season. The sweet potato differs from grain in that the edible portion is not a dried seed that is easily stored and transported but a fleshy root that is highly perishable when storage conditions are not favorable. The storage treatment of the sweet potato is quite different from that of

most food products, and successful storing from one growing season until the next demands certain rather exacting procedures.

Some aspects of this problem that are now common knowledge must have been learned with great difficulty and only after many failures. The two fundamental principles of keeping sweet potato roots from rotting and in a viable condition until planting time are proper curing and relatively warm storage. Even today, however, in spite of our many ways of disseminating knowledge, the importance of these two principles is not adequately appreciated by some people engaged in the handling and marketing of the sweet potato. What meager and fragmentary history we have of the curing and storing of this crop must be gleaned from a number of obscure sources or deduced from such sources as ethnological accounts of the peoples of temperate climates who first used the sweet potato for food.

A brief discussion of the physiology of the stored sweet potato is necessary before reporting the early records on storing. While the sweet potato is growing in the field there is an inflow to the roots of food materials manufactured by the leaves, which is suddenly stopped when they are dug. The roots then undergo a period of "curing." Usually special conditions of temperature and humidity are supplied during this curing period, although in some favored areas storage house temperatures and humidity conditions are such that little artificial control of these factors is required. One of the important and obviously practical functions of curing is the formation of periderm, or callus, over the wounds, particularly those where the roots have been severed. This periderm, or wound callus, helps to prevent the entrance of rot organisms.

After curing is effected a different treatment is necessary for storage, but there is apparently no sharp dividing line between a cured and a non-cured sweet potato. In the curing treatment we seek to provide the optimum conditions for certain physiological and structural transformations to take place. In storage, on the other hand, we endeavor to provide conditions that will enable life activity to proceed, but at as slow a rate as possible. The conditions now used for curing and storing the sweet potato are different from those required by many other plant products, such as apples, turnips, cabbages, and white potatoes, for example. The present-day curing practice ordinarily consists of subjecting the freshly dug roots to a high temperature (85°–90° F.) and a high relative humidity (85–90 per cent of saturation)

for about a week to ten days. Since curing is vital to the storage life of sweet potatoes, it would be interesting to know how and when this important practice originated. A study of the food-handling practices of certain primitive people and of the early literature on the sweet potato indicates that some kind of treatment, which at least partially fulfills the physiological need of curing, has been known and practiced for many years.

The sweet-potato storage practices of the Maoris of New Zealand—early inhabitants of a temperate climate—have been in effect for many centuries.¹⁰ These people followed a fixed ritual when they harvested and stored sweet potatoes. On the appointed day, when all the signs were right, digging was started in the morning (but not before sunrise). By noon the digging ceased, and in the afternoon the sweet potatoes were stored. The Maoris used well-constructed underground storage houses dug in the side of a hill. The sweet-potato house was probably the most important building in the village, and the entrance was often elaborately carved with figures to keep out evil spirits and thus prevent spoilage. The usual storage procedure was to cover the floor with a layer of gravel an inch deep and then with a layer of rotten wood. The seed stock for the next year was selected and stored in the back of the house, separated by fern leaves from the sweet potatoes that were to be used as food. After the seed stock was put into the house, the best of the food potatoes were stored. Finally, the bruised and cut roots were stored near the entrance, where they would be used first. Any important task involving the sweet potato was done communally, so as to finish it the same day it was begun. The storage house was thus quickly filled. It was then tightly closed, and a charm put upon it by the priest adept.¹¹ No one was allowed to enter until a certain period of time had elapsed; then the charm was removed by appropriate ceremonies. During the charm period, when the house was full and tightly closed, conditions were undoubtedly favorable for curing. High relative humidity and a comparatively high temperature would soon develop as a result of the respiratory activity of the potatoes themselves. The Maori introduced the sweet potato into their country from some Polynesian island where the climate was such that there was no storage problem, and, since the sweet potato is very exacting in its storage requirements, it is a noteworthy accomplishment of this primitive people that they developed a successful method of preserving this important food plant for seed and food from one season to the next. The Maoris, however, must

have experienced losses from rot, since the priests told the people that unless all points of the ritual were strictly followed the sweet potatoes would spoil.¹²

Let us now return to the subject of the early literature in the United States on the storing of sweet potatoes. The meager and scattered writings of early colonial times dealing with this subject indicate that it was known that warm storage is necessary for the successful keeping of sweet potatoes. Beverley, in his history of Virginia written in 1705, makes the following statement about the sweet potato:

Their potatoes are either red or white, about as long as a Boy's leg, and sometimes as long and big as both the Leg and Thigh of a young Child, and very much resembling it in Shape. I take these kinds to be the same with those, which are represented in the Herbals, to be Spanish Potatoes. I am sure, those called English or Irish potatoes are nothing like these, either in Shape, color or taste. The way of propagating potatoes there, is by cutting the small ones to pieces, and planting the cuttings in hills of loose earth: But they are so tender, that it is very difficult to preserve them in the Winter; for the least frost coming at them, rots and destroys them; and therefore people bury 'em under Ground, near the Fire Hearth, all the Winter, until the Time comes that their seedlings are to be set.¹³

The importance of curing sweet potatoes was apparently realized long ago by Europeans. As early as 1525-35 Oviedo (as quoted by Gray and Trumbell¹⁴) wrote: "When the Batatas are well cured they have often been carried to Spain when the ships happen to make quick passage but more often they are lost on the voyage." He places special emphasis on the importance of curing to prevent rot. It is true that curing in those times did not carry the definite connotation that it now carries. Even today, however, we know very little about the physiology of curing sweet potatoes.

It would be interesting to know how a fact of such fundamental importance as warm storage in the keeping of a food product was learned. It may have been that information was acquired many generations ago when an Indian tribe on the border of a tropical region carried the sweet potato from a tropical to a more or less temperate climate. Probably after many failures in keeping sweet potatoes they finally discovered the proper method. After the essential features of successful storage were discovered, the method could be readily transmitted from person to person wherever the sweet potato was carried. For the colonial Virginia farmer the idea of providing warmth to preserve such a food product must have been quite an innovation. His experience with other products had taught him that apples, cabbage, turnips, and

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potatoes keep better in cool than in warm storage, and he would naturally expect to store sweet potatoes in the same way.

Among the records of sweet-potato storage is an article by Joseph F. O'Hear²¹ in the *Southern Farmer and Market Gardener*, published at Charleston, South Carolina, in 1852. He gives the details of the construction of a sweet-potato cellar in which heat was used. He recommended that the sweet potatoes be piled on poles and a smoky fire be made every day for three or four weeks. He put special emphasis on smoke, but heat rather than smoke was probably the important factor. This is one of the earliest records of the use of heat in the curing of sweet potatoes.

Knowledge of the difficulties in the storage of

the sweet potato is reflected in the writings of Sir Joseph Banks²² on some horticultural observations selected from French authors. He says: ". . . the slightest scratch predisposes them to rot. They must be kept free from frost and damp; if exposed to either of these, they exhale an odour like that of the rose, and rot immediately. . . ."

At any rate, the transfer from a tropical to a temperate climate necessitated the devising of methods of storage to provide food in winter and to keep the roots in viable condition until the next planting season. Somehow the early users of the sweet potato learned the fundamental requirements for successful winter storage, the need for a cure or conditioning treatment, and for a warm storage place.

References

1. CARRIER, L. *Beginnings of Agriculture in America*. New York: McGraw-Hill (1923).
2. STURTEVANT, E. L. *N. Y. State Dept. Agr. 27th Ann. Rept. 1918-1919*, 2, Part II (1919).
3. CANDOLLE, A. DE. *Origin of Cultivated Plants*. Boston: Appleton (1890).
4. KING, J. R., and BAMFORD, R. J. *Heredity*, 28, 279 (1937).
5. MORLEY, S. G. *The Ancient Maya*. (2nd ed.) Stanford: Stanford University Press (1947).
6. STEWARD, J. H. (Ed.). *Handbook of South American Indians*. Smithsonian Inst. Special Pubs., Bull. 143, 2 (1946).
7. BIRD, J. *Natural History*, 57, 296, 334 (1948).
8. TERRA, H. DE. *Tepexpan Man*. New York: Viking Fund (1949).
9. CARTER, G. F. *Sci. Monthly*, 70, 73 (1950).
10. BEST, E. *New Zealand Dominion Mus. Bull.*, 9 (1925).
11. DIXON, R. B. *Am. Anthropol.*, 34, 40 (1932).
12. COLENSO, W. *Trans. Proc. New Zealand Inst.*, 13, 1 (1880).
13. BEATTIE, H. J. *Polynesian Soc.*, 27, 132 (1918).
14. CARTER, G. F. *Southwest J. Anthropol.*, 6, 161 (1950).
15. HORNELL, J. J. *Linnean Soc. London, Botany*, 53, 41 (1946).
16. CARTWRIGHT, B. J. *Polynesian Soc.*, 38, 105 (1929).
17. LAUFER, B. *Sci. Monthly*, 28, 239 (1929).
18. CHRISTIAN, F. W. J. *Polynesian Soc.*, 6, 123 (1897).
19. BEST, E. *New Zealand Dominion Mus. Bull.*, 5, (1916).
20. GRAY, A., and TRUMBELL, J. H. *Am. J. Sci.*, 3rd ser., 25, 241 (1883).
21. O'HEAR, J. F. *Southern Farmer and Market Gardener*. Compiled by Francis Holmes and William R. Babcock. Charleston, S. C. (1852).
22. BANKS, SIR JOSEPH. *Roy. Hort. Soc. Trans.* (3rd ed.), 1, 4 (1820).



SCIENCE ON THE MARCH

EXPERIMENTING WITH SOIL

THE 108th wheat crop is growing on Broadbalk field at the Rothamsted Experimental Station in England. This historic field in Hertfordshire has a great deal to tell us today. It was laid down by Lawes and Gilbert, who began their field experiments at Rothamsted in 1843 and carried on their partnership for over fifty-seven years. Their classical experiments laid the foundations of our scientific knowledge of the manuring of crops and are still giving us valuable information.

The unmanured plot on Broadbalk continues to give a yield of about 12 bushels per acre, about the world average; the plot receiving 14 tons of farm-yard manure every year yields about three times that amount, and so does the plot which receives a fairly heavy dressing of "complete" fertilizers and

which has had no organic manure since 1839. There is no evidence that the produce from the fertilizer plots is in any way inferior to that from the dunged plot, nor has the soil suffered from the long-continued fertilizer treatment. The fertilizer plots still maintain a normal population of earthworms and microorganisms, and the crops grown on them are not more susceptible to disease than those receiving organic manures.

Since the days of Lawes and Gilbert the soil work at Rothamsted has been greatly expanded. As a result of the statistical research of R. A. Fisher, the methods of field experimentation have been much improved, and the more recent Rothamsted experiments are laid out in such a way that greater accuracy is obtained. These new methods have been



The famous Broadbalk field at Rothamsted, which has grown wheat each year for more than one hundred years.



Experiment being carried out at Rothamsted to test the growth of broad beans.

applied all over the world, not only in agricultural investigations but also in many other branches of research.

Microorganisms. The early soil work at Rothamsted supplementing the field experiments was chiefly chemical and botanical, though as long ago as 1877 Robert Warington began investigating the soil microorganisms and opened a field of research which has been greatly expanded.

In recent years much attention has been given to the nodule bacteria of leguminous plants and also the general study of the soil's population of microscopic living things. It was found, for instance, that in many parts of Britain the nodule-forming bacteria of alfalfa were not present in the soil, and it was impossible to grow the crops satisfactorily without introducing them.

At the present time the nodule bacteria of clovers are being studied. In certain districts the bacteria are of a type that does not collect nitrogen satisfactorily, and the possibility of introducing more effective types is being investigated. If this can be done, it will lead not only to more vigorous growth of clover and an improvement in pastures but also to a building up of soil fertility.

Studies are also in progress on the physical properties of soils, and valuable information has been

obtained on the movement of soil water. It has been shown, for instance, that, as far as moisture conservation is concerned, the chief benefit of hoeing and other surface cultivations is the destruction of weeds, and not the formation of a surface mulch as was at one time believed. The weeds make heavy inroads not only on the water supplies but also on the plant nutrients.

Salt for sugar. The Chemistry Department is continuing the early investigations on organic manures and fertilizers; in particular, a thorough study has been made of the manuring of sugar beet. As a result, the manuring of this crop has been put on a much more satisfactory basis. It was shown in the course of these investigations that the addition of salt increases the yield.

Another line of work is the study of deficiencies of substances such as boron and manganese, of which only minute quantities are required by plants. The manuring of forest nurseries is also being investigated, and results of practical importance have already been obtained. Other work includes the placement of fertilizers close to the seed.

A department has recently been established to study soil formation and classification, and Rothamsted is now the headquarters of the Soil Survey for England and Wales.

Until about thirty years ago most of the soil research in Britain was done at Rothamsted, but soil studies are now carried out at several other centers. In 1930 the Macaulay Institute for Soil Research was established in Scotland, and an extensive program is in progress there. This includes investigations on soil fertility, pedology, soil organic matter, plant physiology, and spectrochemistry. For a number of years the Macaulay Institute was engaged on problems connected with the reclamation of peat land, and a valuable piece of work has been done on cobalt deficiency, which causes the disease known as "pine" in sheep.

At the Horticultural Research Station at Long Ashton, in Somersetshire, England, a great deal of soil work has been done, particularly on fruit soils, and special attention has been given to trace element deficiencies. Soil investigations are also in

progress at a number of universities. At the University College of North Wales, for example, much attention has been given to studies on soil formation and to soil surveys; in Cambridge, England, soil drainage is being studied; and there are active soil departments at Oxford and Aberdeen.

Soil advisory work among farmers in England and Wales is carried out by the National Agricultural Advisory Service, and in Scotland by the agricultural colleges and the Macaulay Institute. An increasing number of farmers are making use of these advisory services, and liming and manuring practice is being steadily improved throughout Britain.

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New Books Received

The Chemistry of Hydrazine. L. F. Audrieth and Betty Ackerson Ogg. xii + 244 pp. Illus. \$5.00. Wiley, New York. 1951.

Man Is a Microcosm. J. A. V. Butler. vi + 162 pp. Illus. \$3.00. Macmillan, New York. 1950.

Associative Evolution—The Prophecy of Isaiah. Morris J. Spivack. 75 pp. Mimeo-stencil ed. \$2.00; blueprint ed. \$5.00. Author. 455 Coney Island Ave. Brooklyn, N. Y.

Quantitative Analysis. (3rd ed.) William Rieman, III, Jacob D. Neuss, and Barnet Naiman. x + 523 pp. Illus. \$5.00. McGraw-Hill, New York. 1951.

La Planta de Trigo, Morfología y Fisiología. J. de Carvalho Vasconcellos. xi + 201 pp. Illus. (No price given.) Instituto Nacional de Investigaciones Agronomicas, Madrid. 1950.

A Field Guide to the Butterflies. Alexander B. Klots. xvi + 349 pp. Illus. \$3.75. Houghton Mifflin, Boston. 1951.

On the Origin of Species. (Reprint of 1st ed.) Charles Darwin. xx + 426 pp. (No price given.) Philosophical Library, New York. 1951.

The Young Scientist. Maitland P. Simmons. viii + 164 pp. Illus. \$3.00. Exposition Press, New York. 1951.

Inventories of Apparatus and Materials for Teaching Science. Vol. II, Universities. 145 pp. \$2.00. Columbia University Press, New York. 1950.

Men of Other Planets. Kenneth Heuer. x + 160 pp. Illus. \$3.00. Pellegrini & Cudahy, New York. 1951.

Human Fertility: The Modern Dilemma. Robert C. Cook. viii + 380 pp. \$4.50. Sloane Associates, New York. 1951.

Chimie Minérale Théorique et Expérimentale (Chimie Electronique). Fernand Gallais. 810 pp. Illus. 2,800 fr. Masson, Paris. 1950.

The Growth of Scientific Ideas. William P. D. Wightman. xii + 495 pp. Illus. \$5.00. Yale University Press, New Haven. 1950.

An Illustrated Manual of California Shrubs. Howard E. McMinn. xi + 663 pp. Illus. \$6.50. University of California Press, Berkeley. 1951.

Bibliographic Organization. Jesse H. Shera and Margaret E. Egan, Eds. xii + 275 pp. Illus. \$5.00. University of Chicago Press, Chicago. 1951.

Letters on the Ornithology of Buenos Aires. W. H. Hudson. xv + 93 pp. \$2.75. Cornell University Press, Ithaca, N. Y. 1951.

The New Physics. C. V. Raman. 144 pp. \$3.75. Philosophical Library, New York. 1951.

Organic Chemistry. (3rd ed.) E. Wertheim. xii + 958 pp. Illus. (No price given.) Blakiston, Philadelphia. 1951.

The Sea Around Us. Rachel L. Carson. vii + 230 pp. Illus. (No price given.) Oxford University Press, New York. 1951.

Possible Future Petroleum Provinces of North America. xiii + 358 pp. Illus. (No price given.) American Association of Petroleum Geologists, Tulsa, Okla. 1951.

Artificial Fibres. R. W. Moncrieff. x + 313 pp. Illus. \$4.50. Wiley, New York. 1950.

Is Another World Watching? Gerald Heard. xiv + 183 pp. Illus. \$2.75. Harper, New York. 1951.

Genesis and Geology. Charles Coulston Gillispie. xiii + 315 pp. \$4.50. Harvard University Press, Cambridge, Mass. 1951.

A Study of Classic Maya Sculpture. Tatiana Proskouriakoff. xi + 209 pp. Illus. \$5.75, paper; \$6.25, cloth. Carnegie Institution of Washington, Washington, D. C. 1950.

Hyperbrachycephaly as Influenced by Cultural Conditioning. J. Franklin Ewing. x + 100 pp. Illus. \$3.75. Peabody Museum, Cambridge, Mass. 1950.

An Index of Mediaeval Studies Published in Festschriften, 1865-1946. Harry F. Williams. x + 165 pp. \$4.00. University of California Press, Berkeley. 1951.

BOOK REVIEWS

THE DELECTABLE MOUNTAINS

The Incomparable Valley—A Geologic Interpretation of the Yosemite. François E. Matthes; edited by Fritiof Fryxell. xvi + 160 pp., 50 pls., 13 diagrams. \$3.75. University of California Press, Berkeley. 1950.

THIS delightful posthumous book is by an ardent lover of the high Sierra Nevada, especially the truly incomparable Yosemite Valley, which is annually the magnet for hundreds of thousands of visitors to Yosemite National Park. Dr. Matthes' book exemplifies the truth expressed elsewhere by the editor that "true appreciation of landscape comes only when one is alive to both its beauty and its meaning." In the first instance, the author was a topographer who understood so well the inherent nature of land forms that his contour maps had the expressive beauty of etchings; he then became a geologist who was a foremost interpreter of the alpine glaciation of the relatively recent Ice Age and of the characteristic land forms that resulted throughout the Sierra Nevada. A few years before Dr. Matthes' death this reviewer was one of a small party that shared his gracious enthusiasm as he led them over familiar Yosemite trails. Although not a "Son of the Wilderness," as was John Muir, he embodied much of the same spiritual insight into the beauties of nature portrayed in alpine peaks and canyons. He was a quiet but convincing exponent of the unique values to modern men of mountain wildernesses, which found expression also in his active membership in The Wilderness Society.

This brief characterization of Dr. Matthes is given to aid those who did not know him to appreciate better the rare quality of his book. This quality is enhanced most worthily and effectively by the editor—a "mountain man" himself, and the author of *The Tetons—Interpretations of a Mountain Landscape* (Univ. California Press [1938]) aptly reviewed as belonging "in the field of literature as well as of science." The author did not live actually to write the book on the Yosemite which he had long cherished and planned, probably ever since the completion of his masterly professional work on the *Geologic History of the Yosemite Valley*, published in 1930 by the U. S. Geological Survey. The editor has been able through intimate association in body and spirit to weave together notes, manuscripts, and published materials as Dr. Matthes himself would have done. He has modestly and artistically woven many strands into an illuminating tapestry of poetic essence. No book on the Sierra Nevada of such chaste

literary style has appeared since Clarence King's *Mountaineering in the Sierra Nevada* (1874). It should become an enduring classic of the interpretation of geologic science.

Justice cannot be done to the substance or the spirit of the book by a synopsis of its contents; yet such may be desirable for those who are unfamiliar with the high Sierra or the incomparable Yosemite. Devotees of the region may welcome knowledge of the contents of a book that they will wish to add to their libraries. Laymen searching for an interpretation of landscapes and of earth history which they can readily comprehend will here find their need satisfied. It is a book of nature and of science for which no glossary is necessary.

The geologically long and stirring sequence of events that compose the physical evolution of the Yosemite region, from the revolutionary birth of the ancient Sierra Nevada to the present sculptured landscapes, "colossal in scale and superb in composition," is unfolded with clarity, simplicity, and forcefulness. First, however, comes a series of illustrative photographs, many by a peerless photographic interpreter of landscapes, Ansel Adams, and others by various geologists.

The geologic history of the Sierra Nevada is initially epitomized. Then the canyoned Yosemite region is discussed, so that the significance of the individualistic yet intimately related peaks, canyons, waterfalls, and associated landscape features is made known. Next, the Yosemite Valley is described as the dominant note in the immediate landscape, followed by the deciphering of its history through geologic ages. The almost unique and striking domes, such as Half Dome, are interpreted. Attention is then given to the postglacial features of the valley, including the magnificent waterfalls. The geologic story closes with a discussion of the "Little Ice Age," a concept developed by Dr. Matthes, in which he shows that the existing glaciers are not senile remnants of the great Ice Age glaciers (Pleistocene) but are true glaciers in their own right, progeny of a resurgent glacial climate within the annals of human history, begun some 4,000 years ago.

The reviewer would be remiss if he did not remark upon the high quality of the halftones, the excellent choice of type face, and the fine format of the book. It is in all respects a superior volume, which should find its way into the hands and minds of hundreds of thousands who would receive enjoyment and recreation from it.

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Sequoia National Park—A Geological Album. François E. Matthes; edited by Fritiof Fryxell. x + 136 pp., 124 figs. \$3.75. University of California Press, Berkeley, 1950.

THIS is almost a unique book, in that the salient scenic and geologic features of Sequoia National Park are made known and understandable to lay visitors by means of photographs, each of which has a concise explanatory text. Dr. Matthes was eminently fitted for the task through his intimate knowledge of the region and his matchless interpretive skill. The geological album was first prepared in 1938, in three folios, for the National Park Service, until a geologic monograph, similar to that on the Yosemite region, could be prepared. But death intervened; hence Dr. Fryxell has taken the original albums and with slight changes prepared them for a wider public.

The features to be illustrated have been chosen with care to comprise the range of striking phenomena in the magnificent Sequoia National Park in the southern part of the Sierra Nevada. They are arranged under eleven geologic topics, each of which has also a short section of general interpretive text. It is unfortunate that the halftones are not as excellent as they might be; in some instances they are so gray that the features they illustrate are not clear even to a geologist. Apparently either paper or ink was not of satisfactory quality. They are in marked contrast to the fine halftones in the companion book also reviewed here.

This pictorial guide used with another one (*Along Sierra Trails: Kings Canyon National Park*. Joyce and Josef Muench. New York: Hastings House [1947]), prepared by artists rather than geologists, should give visitors to the southern Sierra a deeper interest in, and a clearer understanding of, those superb landscapes.

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CHILD OF THE RENAISSANCE

Giordano Bruno—His Life and Thought. With Annotated Translation of his Work on the Infinite Universe and Worlds. Dorothea Waley Singer. xi + 378 pp. Illus. \$6.00. Schuman, New York. 1950.

GIORDANO BRUNO is known primarily for his incorporation of the Copernican astronomy into a pantheistic cosmology. However, to consider him as either a popularizer of Copernicanism, or a believer in the new astronomy on naturalistic grounds, grievously falsifies his place in the history of thought; he is rather an early example of that now-familiar phenomenon, the thinker who makes use of the conclusions of science for nonscientific purposes. Child of the Renaissance that he was, Bruno boldly combined an infinite universe, a plurality of worlds (solar systems—for him some visible stars were suns, some moons), motion of all the heavenly bodies, and a monadology with a mystical belief in the divine Oneness of things. His sources were mainly Lucretius, Cardinal Nicholas of Cusa, scholastic

philosophy, Plato's *Timaeus*, and Copernicus, whose views had not yet been branded heretical. It is revealing that his cosmological speculations vastly interested Kepler, that Pythagorean mystic, but not Galileo; and that much of his contemporary reputation came from his supposed perfection of an "art of memory," a bit of natural magic derived from Raymond Lull.

Mrs. Singer outlines authoritatively the troubled years of Bruno's life: at seventeen he entered a Dominican monastery; eleven years later he left, to wander incessantly—through Italy, to Paris, to Elizabethan London where his best work was done, through the Germanies, and then, inexplicably rash, back to Venice. There he was denounced to the Venetian Inquisition, which under pressure handed him over to the Roman Inquisition. After seven years' imprisonment he was burned at the stake, in 1600: his views on the Trinity were heretical, he had left the monastery and his vows, and his pantheistic concept of God and the universe was outside the framework of orthodox Catholicism.

Bruno's travels and acquaintances—many and influential, both friends and enemies—are here recounted in thorough and clear detail, though one could wish for more interpretation; a biography that merely states events and ideas fails to satisfy the legitimate demands of the reader. The most useful and enlightening sections are those that illuminatingly outline the content and method of Bruno's cosmological and ethical writings. Most valuable of all is the excellent translation of the Italian treatise *On the Infinite Universe and Worlds*.

There is much that is still inexplicable about Bruno's relations with his contemporaries and with the Inquisition, but this book gives us an opportunity to understand his aims and method. Startlingly sincere and audacious is his firm proclamation: "It is Unity that doth enchant me. By her power I am free though thrall, happy in sorrow, rich in poverty, and quick even in death."

MARIE BOAS

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INVERTEBRATE ZOOLOGY

The Invertebrates: Platyhelminthes and Rhynchocoela. The Acoelomate Bilateria, Vol. II. Libbie Henrietta Hyman. vii + 550 pp., 208 figures. \$9.00. McGraw-Hill, New York. 1951.

THE second volume in the treatise on "Invertebrate Zoology" will reach an expectant public which has long eagerly anticipated its appearance. The first volume has already taken its place as an indispensable reference work in the field. There is no up-to-date comparable work available in English, the nearest equivalent treatises being the much more detailed presentations in the Kükenthal-Krumbach *Handbuch der Zoologie* and the Grasse *Traité de Zoologie*.

The Bilateria as a group are discussed in an introductory chapter, and phylogenetic considerations on each of the two phyla treated in detail are taken up as topics in the discussion outline in the succeeding chapters.

The characterization of each phylum includes a treatment of the historical background, characters of the phylum, classification of the phylum, morphology and physiology, including development and ecology, and phylogenetic considerations.

The author in her prefatory statement makes the important clarification that the contents of her volumes reflect a majority opinion of workers or the opinions of outstanding specialists in a given group, with her own stand on any matter, when expressed, explicitly stated as such. The consistency and lucidity of the presentation emphatically represent that the author has thorough mastery of the material. It is a most unusually encountered and accordingly gratefully appreciated boon to workers having occasion to refer to such a treatise to find a positive stand crystallized out of the maze of published information in the field.

The extent of coverage of the subject matter is expressed by the fifty pages of bibliography, distributed by chapters and compiled in condensed but highly comprehensible form. Titles of articles are quoted and classified to the major headings of treatment. The references included show obviously great care taken to incorporate latest available findings.

The illustrations are presented nominally as figures, although most are in actuality plates including a number of detailed figures. As a part of her plan of presentation the author has personally prepared the illustrations from specimens or made adaptations from published figures. The uniformity so conferred is a most distinct advantage to the user. Many habit figures are presented, so that a thoroughgoing impression of general aspect in the groups under discussion is conveyed. The technical details of morphology and the features of the developmental stages are equally comprehensively illustrated. The successful apposition of figures to subject matter under treatment would appear to reflect unusually careful and competent procedure in planning the composition of the volume. The physical features of the book in all respects conform to the high standards of production of the series in which it is included.

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WHAT'S IN A NAME?

The Piperaceae of Northern South America. (2 vols.)
William Trelease and Truman G. Yuncker. 838 pp.,
674 plates. \$10.00. University of Illinois Press,
Urbana. 1950.

THE Piperaceae, one of the larger families of dicotyledonous plants, is a pantropical group of rather uniform affinity that has baffled more than one taxonomist. In fact, to most workers faced with the necessity of "naming" material, the Piperaceae has presented a seemingly insoluble problem, by virtue of the taxonomically unsatisfactory character of its simple flowers, the elusive features of its gross morphology, and its very size and abundance in nature. A regional revision

of the family, therefore, particularly in the area that seems to represent one of the two main centers of distribution (the other being southeastern Asia and Malaysia), is a highly noteworthy publication in the field of systematic botany.

The family is considered to include two large genera, *Piper* and *Peperomia*, each with several hundred species, and a few small generic segregates. Earlier efforts at its classification were undertaken by Miquel, Casimir de Candolle, and (for Ecuador only) Sodiro. After De Candolle died in 1917, Professor Trelease became interested in the family, especially in the New World, and published revisions for Costa Rica, Panama, and Peru. Before his death, in 1945, Trelease had studied the De Candolle collections at Geneva in connection with a wealth of more recently assembled specimens, and his unpublished notes and manuscripts were voluminous. Professor Yuncker, himself an established authority on *Peperomia* in the Pacific area, was prevailed upon to complete Trelease's work at least in part, and the present revision is the result of his diligent study of all the available herbarium material and his collation of Trelease's papers. That the major contribution to the work was made by the junior author may be surmised, although most of the novelties are attributed to both authors.

Professor Yuncker, in his introduction, anticipates a criticism by stating that the number of new species recognized is extremely large and will perhaps appear unreasonable. The area covered, however, is fantastically rich in individuals of the family; furthermore, comparatively few species of it from this region have been described for more than thirty years, a period of very intensive collecting, often in areas hitherto little known botanically. The treatment is certainly not offered as the last word, for one may suppose that further field study or more abundant collections will necessitate reconsideration of some species, and doubtless a considerable number of undescribed entities await collection.

The keys are frankly artificial and designed to expedite identification. Floral characters are for this purpose unsatisfactory, as a large percentage of herbarium specimens lack mature spikes. Inevitably, foliage and indument characters have been stressed in the keys. The place of deposit of specimens is shown by a standard series of abbreviations. The treatment closes with a bibliography, an indispensable index of collections cited (occupying 61 pages and arranged by genera), and a general index to scientific names.

It has seemed impractical to arrange the species in subgenera or sections, since these, at least as recognized by De Candolle in *Piper*, are differentiated on the number and position of stamens, difficult or impossible to determine in a large proportion of herbarium specimens. The keys have been divided, however, in order to facilitate their use, but the subdivisions are not natural groupings in the taxonomic sense. A treatment of this sort will seem unsatisfactory, if not baffling, to readers who seek phylogenetic implications in taxonomic papers. But in view of the present state of our knowl-

edge of this vast family, one fails to see how Yuncker could have made any other choice but to avoid phylogenetic speculation in favor of practicability.

Descriptions are fairly brief, but adequate; most of the new entities and many older ones are illustrated by halftone plates showing herbarium specimens. These plates are well reproduced and will prove invaluable as an aid to identification, but they must definitely be supplemented by the descriptions for an understanding of essential detail. Although the great number of plates might incline one to think that this is a "picture book" (so dear to a certain type of worker who hopes to "match" material by thumbing through illustrations), such is not the case; the reader who is unwilling to use the keys and the technical descriptions will not be happy with this book—in fact, he would do well to avoid such a family as the Piperaceae altogether.

Although six genera are recognized, two of them—*Piper* and *Peperomia*—contain 97.5 per cent of the species. In this treatment 840 species, many of them further subdivided, are recognized. To one accustomed to comparatively well-known temperate floras, it will come as a slight shock to learn that the authors have felt it necessary to propose 405 species as new, names and descriptions for these being provided in the present work. A major revision in which nearly half the accepted entities are described as new is difficult for many botanists to accept, particularly if they are inured to the conservative species concept that seems to accompany the study of well-known floristic regions. But botanists who have worked with such spectacularly rich flora as that of northwestern South America will find Yuncker's evaluation of specific entities entirely credible, as they recall the profuse occurrence of *Piper* and *Peperomia* in the Andes. It must not be supposed, as is sometimes facetiously claimed, that no species of these genera can contain more than a handful of individuals. Consultation of the very substantial paragraphs of specimen citations, and examination of the extensive synonymy, will demonstrate that many species are very bulky entities, considering the still-cursory state of our knowledge of the actual plant population of northwestern South America.

The only matters of nomenclatural judgment that the reviewer would question are insignificant. For instance, *Peperomia litiana* is proposed as a "sp. nov." without a Latin diagnosis, but one soon perceives that this is actually a new name based upon an earlier trinomial and not a new species. *Peperomia biamenta* is similarly proposed as a "sp. nov." (with a Latin diagnosis), when it is actually based upon the type of a published trinomial and therefore is only a new name. One might also wish that fluent specific epithets could have been found for all the new species, while quite aware that thousands have already been used in *Piper* and *Peperomia* and that the choice is thereby restricted. However, nontaxonomists will not approve such epithets as *caliginigaudens*, *churruyacoanum*, *protractuspidatum*, and *sachatzinzumba*.

It would not be possible to present such a voluminous work without flaws, but the reviewer has found few

mistakes of an editorial or typographical nature, and the accuracy of the geographic citations is a pleasure to note. *Piper rusticum* appears in the text as species No. 90, instead of 190, a trivial error, and sometimes the spacing of paragraphs is uneven in such a way that the beginning of each entity is not immediately apparent. However, the University of Illinois Press is to be complimented on the pleasing appearance of both text and plates. Professor Yuncker is indeed to be congratulated for the high standard of workmanship and the competent attention to detail that are apparent on every page of his work, as well as upon his industry and courage in completing a revision which, by the nature of its basic difficulties, would have discouraged any less accomplished and talented a taxonomist.

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HERITAGE

The Smithsonian: America's Treasure House. Webster Prentiss True. 306 pp. Illus. \$3.50. Sheridan House, New York. 1950.

WERE James Smithson to visit Washington, D. C., today and view the vast and imposing structures of the Smithsonian Institution, he would undoubtedly be amazed at what his bequest has made possible. For, since its founding on August 10, 1846, the Smithsonian has expanded incredibly. In his highly interesting account of the "treasure house," Webster Prentiss True cites statistics that illustrate the tremendous diversification and ramifications of its activities: more than 27,000,000 biological specimens, 17,000 human skulls, 13,000,000 copies of its publications, etc.

The growth of the Smithsonian has not been merely quantitative, however. In carrying out Smithson's original purpose, as stated in his bequest, of an institution designed for the "increase and diffusion of knowledge," the Smithsonian has long carried on an extensive research program of international scope. In an attempt to combat the popular misconception that it is merely a collection, albeit on an unusually large scale, of scientific and other objects of historical interest, the author delves into the research activities of staff scientists, demonstrates the extremely useful aspects of such research, and details the noteworthy services rendered by the Smithsonian during both world wars.

In a delightfully interesting manner, the reader is taken on an extended tour of the treasures on exhibit at the Smithsonian. In nontechnical language (since the book is intended for the layman) the lines are traced along which the treasure house is organized, and examples of the various exhibits are neatly presented. A delicious repast is spread before the reader, whose appetite is skillfully whetted by choice intellectual bites. Whether his interest is in our planet earth or in the myriad forms of life on it; whether in the anthropologists of prehistoric and modern man on our continent, or in the past and present of the American Indian; whether

in the historical collections associated with our country's great history, or in the story of America's mammoth industries; whether in the latest researches concerning the sun or in those dealing with the innumerable galaxies of the universe—there is more than enough at the Smithsonian to satisfy a multitude of interests. Besides the National Museum, the Washington Zoo and the National Gallery of Art—also part of the Smithsonian—attract hordes of visitors, and the sights on view are not easily forgotten.

The author's aim of enlarging our knowledge of the activities and the treasures on exhibit at the Smithsonian by presenting the material in a manner designed to hold the interest of the average reader is accomplished in admirable fashion. Too often has the educated layman thrown away in disgust a volume meant to increase his interest in and understanding of scientific phenomena after spending several uncomfortable hours trying to master material poorly presented and written in scientific gobbledegook. True has avoided such mistakes in the difficult task he has tackled. He has also avoided the twin pitfalls of faulty generalization and inaccurate presentation of scientific data.

In view of the interesting and competent manner in which the book is written, it is regrettable that the author has failed to include a bibliography, which would certainly be profitable to those interested in knowing more about "America's Treasure House."

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EVALUATING APTITUDE AND ACHIEVEMENT

Theory of Mental Tests. Harold Gulliksen. xix + 486 pp. Illus. \$6.00. Wiley, New York, 1950.

PSYCHOLOGY has long needed an advanced textbook covering the theoretical background and statistical procedures involved in the construction of aptitude and achievement tests. Gulliksen's book excellently fills that need. Material that has been available only in considerably older books and scattered original sources is here brought up to date and, in several cases, extended by Gulliksen's own work.

Basic test theory formulas are derived both from a definition of random error and from a definition of true scores. The book then covers the following major topics: errors of measurement, substitution, and prediction and different interpretations of the errors of measurement; effects of test length on reliability, validity, and other test parameters; effects of group heterogeneity on test reliability and validity and corrections for restricted heterogeneity; criteria for parallel tests; methods of obtaining and estimating test reliability; speed versus power tests; methods of scoring tests and of standardizing and equating test scores; weighting and differential prediction; and item analysis.

Throughout the book the author has assumed that the reader knows elementary statistics, algebra, and analyti-

cal geometry. In specific portions he has also assumed somewhat greater mathematical preparation, including, for part of one chapter, matrix algebra. The chapters and sections are sufficiently independent so that students with the minimum background can understand those parts for which more advanced preparation is not specifically assumed.

Persons concerned about problems arising in other types of psychological measurement, such as attitude measurement or personality scales, will profit from a study of the solutions to similar problems which have already been worked out in test theory. But the book is primarily intended for those working in test development. For students in this field it will be a valuable textbook; for students, teachers, and test developers it will be a standard guide and reference work. Users will welcome not only the derivation and interpretation of the formulas applicable to testing problems, but also the discussions of the conditions of their appropriate use and the many computational aids and working procedures that are described.

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RESEARCH AS ART

The Art of Scientific Investigation. W. I. B. Beveridge. xii + 171 pp. \$3.00. Norton, New York, 1950.

SO MUCH is written about the orderliness, the step-by-step procedures of scientific method, research, and discovery, that one is apt to get the impression, falsely, of an all-knowing cookbook guiding the disciplined and obedient scientist and inevitably directing him to unmask the unknown. However, when one reflects on the basis for this conception, the reason turns out to be quite plain. For books *about* science get their material and inspiration from books *on* science, and these latter usually present their case in accordance with the precepts promulgated by the former!

No one who has not undertaken scientific research can fully appreciate the unexpected difficulties, the trying change of plans, the hit-or-miss procedures, and, yes, the unexpected ease at some points, that often arise to plague, puzzle, or please the researcher. It is altogether gratifying, therefore, when a scientific researcher undertakes to raise the mysterious curtain of science, exposing his research activities and those of his fellow-scientists, and unashamedly allowing the public gaze to focus on the "dirty linen" that otherwise is often carefully concealed or censored from the finished product. Professor Beveridge, the distinguished director of the Institute of Animal Pathology at the University of Cambridge, has done just that.

Erratic chance, elusive imagination, and impulsive intuition are forcefully exhibited as the triumphant heroes of fruitful scientific discovery. And once exalted reason is dethroned and relegated to the ancillary sphere of "verification, interpretation, and development." Bravo to all this! Indeed, most of the book might

readily have been devoted to showing how reason has often held back or stifled original "mad" ideas—ideas which, by pure doggedness on the part of their originators or disciples, were shown later to be of tremendous fertility in the over-all scientific enterprise. Presented, also, are many useful hints based on the experience of the author and of many others, to help the researcher plan his experiments and get the most from his capacities of imagination and intuition.

Biologist that he is, Beveridge has chosen most of his examples from the research of others in his own specialty, but there is a good sprinkling from the other sciences as well. The young researcher is especially apt to profit from this book by avoiding the pitfalls encountered by others, taking advantage of their fruitful experiences, and deriving encouragement in difficult periods from the knowledge of the not-infrequent discouragements of even the world's most renowned scientists. In fact, the book is largely addressed to the young researcher or the one about to enter upon such a career.

One note of criticism: Beveridge does not lay much value on courses in the philosophy of science for science students, but does not say why. He does, however, think that courses in the history of science could be helpful. One wonders how the latter could be given in an adequate manner without taking into account the changing philosophies of science held at different periods and how these affected in good measure the type of science characteristic of a given period.

The book is well worth reading and, though quite elementary, the thesis proposed might well serve the useful function of reminding the busy scientist that "scientific research is still an art or craft."

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PSYCHIC HYDROLOGY?

Henry Gross and his Dowsing Rod. Kenneth Roberts.
310 pp. Illus. \$3.00. Doubleday, New York. 1951.

HERE is something so impressive about the performance of an experienced dowser that the average up-country family needing water sings praises loud and far for its down-to-earth benefactor. Statistics would be difficult to gather, but probably a substantial part of the family-size wells in this country have been dug after seeking or accepting the advice of a dowser or water witch.

The equipment used by most is very simple: a forked twig of apple, witch hazel, or one of a variety of other deciduous trees, preferably fresh-cut. The dowser grasps the two ends, holding his hands palm-side up. With the apex of the V held aloft he takes off afoot, and when it dips and points downward it indicates to the performer that a water vein is below. From this point on, local practices and individual variations embellish the artistry of each diviner.

In some circumstances he may take it upon himself

to predict the depth to the water, its rate of flow, its temperature, whether it is drinkable or not, what kind of soil, gravel, or rock the well-digger will encounter, whether your wife's first cousin's neighbor 200 miles away can locate his well successfully within 20 feet of his house, whether there's water on Bermuda, on the moon, or on Mars, and sometimes the location of liquids having more than 3 per cent of alcohol—especially if such supplies are bourbon or hard cider. At least the story of Henry Gross and his dowsing rod as told by Kenneth Roberts records such feats and more. "The dowsing rod, in the hands of a skilled dowser, seems to be invariably accurate," says the author.

He goes on:

No human activity is infallible; but so far as the behavior of Henry's rod is concerned, it is as close to infallible when operating under natural conditions as anything can be. My primary reason for writing this book was to place on record the peculiar facts in the case of Henry Gross, so that they might readily be consulted by amateur and professional dowsers. But I had another reason. I wanted to make a plea to scientists who have investigated, or think they have investigated, dowsing.

Yet scientists may ask how it was possible, for example, for Gross, Roberts, and Company to locate what they describe as "domes" of fresh water in Bermuda yielding at the rate of 44 and 81 gallons a minute, by drilling down lower than sea level from high points on the island? The author asserts that there was no fresh water—no spring water—in Bermuda. "All drinking water was rainwater, trapped by the whitewashed roofs of all Bermuda buildings, and by whitewashed rock rain catchers. . . ." A few moments' research in a good textbook on ground water will show that limestone islands of the Bermuda type have little fresh water because the limestone is so permeable that rain water runs through it rapidly and mixes with the salt water. Nevertheless, most of these islands (Bermuda included—as has long been known to hydrologists) have a thin lens of fresh water floating on salt water, its thickness depending on the size of the island, the permeability of the rock, and the rainfall. The problem is not that there is no fresh water, but that there is not very much. What there is must be developed by a "skimming" process in which wells or galleries are dug to or just below sea level and the water is pumped at a rate that will keep its level just above that of the sea and thus prevent salt water from rising into the well or gallery.

Mr. Roberts has succeeded admirably in recording the outward manifestations of his neighbor's performances, but if he hopes to win over natural scientists to the point where they are willing to make concessions to psychic "hydrologists" of the homespun variety, then he should change his belligerent tactics. His current work is too much in the nature of attempting to make an Irish terrier lie down beside a strange cat.

Men of broad scientific background are quite willing to grant that some individuals are more sensitive than others to changes in the strength and polarity of electrical fields associated with both natural and artificial objects. S. W. Tromp, a Dutch geologist who has taught

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at Fouad I University, Cairo, and is now with the United Nations, appears to have demonstrated just that, through carefully controlled experiments that rule out other explanations (including, at least in some cases, mind reading) for the observed "dowsing phenomena." His demonstrations, in part, have been confirmed by direct electrical measurements. (See his book, *Psychical Physics, A Scientific Analysis of Dowsing, Radiesthesia, and Kindred Divining Phenomena*. New York: Elsevier Pub. [1949].) But even a scientist like Dr. Tromp does not appear to claim that dowsers can identify the cause of a particular change in electrical field strength, but only that it exists. Nor does he support the claims of "map dowsers."

It is interesting to observe that water witches are most successful in areas where the small supplies of water they are seeking are so universally present beneath the surface that it would be a real accomplishment to avoid striking water. Such conditions are very widespread, for in only a comparatively small part of the earth's land area is it impossible to obtain the small ground-water supplies needed for household use, though large supplies for industrial use or irrigation are something else again. Difficult areas include some extreme desert areas and some areas of unusually dense, unfractured rocks that absorb little or no water from precipitation.

Statistics can be made to lie, but they can be made to tell the truth, too. In New South Wales, the government as a matter of interest has kept records as to which of several thousand well locations have been dowsed and which have not. Over the years the dowsed wells have been consistently less successful than those found by other means, indicating that chance or plain common sense is a little more reliable. On the basis of Dr. Tromp's findings, it may be that New South Wales dowsers are detecting changes in electrical fields originating from a variety of sources; but that they are locating water is challenged by the record.

Roberts' faith in Henry's rod is unshakable. He records, for example, that many persons find dowsing rods working strongly in their hands when they follow in the footsteps of a skilled dowser, but when left to their own devices their rods dip equally strongly over spots that have no attraction whatever for the rod of the gifted dowser. Is this not an argument for "educated reactions" or autosuggestion? Just how great a part does the dowser's acquired (and perhaps unconscious) knowledge of elementary hydrology and geology play in the practice of this art?

This book shows that education has a great deal to do with it, for Kenneth Roberts tackled the subject of dowsing as he would tackle a subject involved in any of his superb historical novels. The wealth of his quotations from water literature both past and present, and the extent of his travels and researches into the various ramifications of dowsing as practiced over the centuries and throughout the world, indicate that his own knowledge in these fields grew considerably in the years following his first experiences with Henry Gross. As the author's knowledge grew, so did his expectations of in-

creased performance on the part of his favorite dowser. He was not disappointed at any stage. The ability of Henry's rod to keep up with Roberts' educational progress was remarkable.

It is especially hard to believe that any "dowsing ability" is involved when Henry "asks his rod" all manner of questions after the manner of the Delphic oracle—the rod pointing down for answers in the affirmative and remaining upright for negatives. One trained in scientific methodology naturally wonders what other factors are involved in such phenomena as long-distance dowsing, or locating such things as minerals, oil, fugitives from justice, gold watches and brooches, anchovies, tourmaline, and scotch. Why is a twig that works for bonded bourbon suddenly silent where blended spirits are concerned? How great a connection is there between certain bizarre dowsing performances and old-fashioned spiritual seances with floating tables and horn rappings?

Although Mr. Roberts may have failed to stir up any kindred appreciation among scientists for the fine points of Higher Doodlebugging, the fact remains that there is an unexplained or only partially explained power involved. Increased human knowledge apparently gives added ability. Yet if dowsing is based on natural laws, as experienced diviners claim, the approaches suggested by Dr. Tromp are more likely to impress men of research than is the less scientific though perhaps more dramatic approach of a novelist.

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WORDS, THE SIGNS OF IDEAS

Interlingua-English Dictionary. Alexander Gode, Ed. Ixiv + 415 pp. \$5.00. Storm Publishers, New York, 1951.

TAKEN by itself, this book leaves a rather odd impression. It purports to contain the vocabulary of the international language which "exists potentially in the common elements of the speech forms of huge segments of civilized mankind." Even a cursory examination reveals a stratum of technical terms from Greek—familiar like *barometro*, unfamiliar like *cyanogramma* for *blueprint* (but *gramma* does not mean "print"); another stratum taken directly from Latin—*adhuc*, *apud*, *olim*, *sed*; a large stratum of Latin words remodeled in the interest of uniformity; and a liberal sprinkling of words taken directly from single living languages—*consپuer*, *Poltergeist* (but not *Zeitgeist*), the inevitable *bar*, *cocktail*, and *whisky*, along with *beefsteak* and *roast beef*. All this purports to be "the natural choice for the vocabulary of an international language based on the common features of the languages of Western civilization."

The processes by which the words of this language are selected and normalized must be studied in the introduction; they cannot be summarized in a brief note. In essence, however, they seek to establish a basic form which is sometimes Latin, sometimes Latin modified in an effort to arrive at a form "potentially" present, with

the aid of "a parallel between formal and semantic continuities." It makes sense to say that Latin *episcopus* is latent under the various forms of *évêque*, *vescovo*, *obispo*, and *bishop*, and it is permissible to adopt the modification *episcopo* for the new language, if one likes; but *quia* for *because*, or *sed* for *but*, is not latent in the forms of any modern language, and to adopt such a form is merely an arbitrary way of cutting the knot. The allusion (p. xxxv) to forcing certain forms back into the Latin pattern might be thought to betray the cloven hoof. It is very well to say that "the resultant form must never be conditioned by a trait restricted to one single controlling variant," but why accept an entire word from a single language in some cases, and go through the laborious process of reduction to type in others?

In short, it is questionable whether this assorted word stock can fairly be called international, even for the world of Romance and English speakers for whom it is designed. Unity of form admittedly does not cover unity of meaning; and the principles of spelling and pronunciation are also fluctuating, with certain familiar difficulties rather evaded than met. One might imagine a group of scientists writing in this language, but it is very hard to imagine even scientists conversing in it, or to suppose that it could become a medium for everyday communication. A strict Neo-Latin is an understandable idea; but the attempt to make it flexible by working in assorted linguistic strands yields a product that is no more logical than any actual language, and certainly less homogeneous. Only time can tell whether Interlingua is really a step toward a workable international language or a monument of misplaced effort.

General Phonetics. R-M. S. Heffner. xvii + 253 pp. Illus. \$7.50. University of Wisconsin Press, Madison. 1950.

THIS book, dedicated to the memory of Karl Hochdoerfer and Charles Hall Grandgent, gives a lucid and well-arranged survey of its double field: the production of vocal sounds and the nature of the sounds produced. The two chapters of Part I discuss the physiology of the speech organs and, in somewhat less detail, the main features of the physics of speech sounds. Part II begins with an excellent short chapter on criteria of analysis, which leads to the conclusion that every conventional orthography is more or less inadequate, and that even the best phonetic transcriptions "are wholly unambiguous only to a reader who knows the precise regional dialect represented." In each language we find a limited number of speech sounds, and certain regular features of the fusions of these forms. Two chapters then discuss, in much detail, the syllabic sounds or vowels, and the nonsyllabic consonants or stops; and a final one examines the often curious changes that befall speech sounds in context, with a fascinating variety of illustrations from many languages and dialects.

The author handles this diversified material with a refreshing absence of dogmatism, and a quiet eye for picturesque aspects as they appear. I may mention as

instances the treatment of the notorious "New England *r*" on pages 187-88, with its mild verdict that "Eastern American speech uses the hiatus breaker *r* in forms in which it is not etymologically justified at all," and the brief account of group stress and rhythm on page 227. Any reader who is interested in what mankind has done with the relatively few vocal sounds at its disposal will find in this book ample material for reflection.

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ZOOLOGICAL TEXT

Comparative Animal Physiology. C. Ladd Prosser, Ed. 888 pp. Illus. \$12.50. Saunders, Philadelphia. 1950.

THE purposes of this book, to quote the authors' own words, are to serve: "(1) as a textbook for use in courses in comparative physiology at the advanced undergraduate-early graduate level by students with some background in zoology and mammalian physiology; (2) as a source book of sufficient detail and bibliography adequate to introduce investigators to particular branches of the subject." A book fulfilling either one of these aims would be desirable in itself, as anyone can testify who is faced with the problem of finding a suitable text in English for a comparative physiology course or who attempts to orient himself within some restricted segment of the voluminous literature on the subject. The very nature and scope of the subject in its broadest implications almost require that any effort to discuss it with any degree of authority be a matter of collaboration rather than the work of any one individual. It is evident that the authors have expended much effort to accomplish a greatly needed and worth-while task, with extremely gratifying results. In general, they have exercised sound judgment of exclusion and inclusion—inclusion of pertinent material from an immense array of data spread throughout innumerable journals (in not a few languages) and exclusion of data that would be perhaps interesting but superfluous.

There are 23 chapters (13 entirely by the editor on such topics as: Water, Inorganic Ions, Protein Specificity, Nitrogen Excretion, Photoreception, Phonoreception, Mechano- and Equilibrium-Reception, Muscle and Electric Organs, and Bioluminescence, plus the usual matter concerned with the various common physiological systems. Some chapters, such as those on nutrition and digestion, appear to be a mere summary or survey of the literature; others, such as those on nervous and endocrine mechanisms, are more imaginatively written. The chapters on stimulus reception are of particular value in bringing together material from recent investigations not previously readily available in textbooks. Not all the writing is of an even quality, no doubt because of the composite nature of the enterprise. The writers are of course best when they are writing about their own particular fields.

The organization of the chapters into subdivisions of up to three orders by sectioning, boldface type, and italics facilitates readability as well as use as a reference

work. There are numerous line drawings, graphs, and tables which summarize experimental results of phylogenetic interest from various sources. A substantial bibliography (including complete titles of reference papers) closes each chapter. The decision to organize the text on a subject-matter rather than on a phylogenetic basis alleviates the tendency to obscure the physiology in favor of the comparison, to miss the forest for the trees. As a text, it presupposes some previous acquaintance with the invertebrates in order to appreciate fully the significance of many of the data drawn upon in the discussion.

In spite of the excellence of this volume as a text, it is the reviewer's opinion that its usefulness could have been extended to meet the need of the student who has not had the prerequisite physiological preparation (as by the authors), but who still has an interest in comparative physiology. The text is too difficult to use in such instances without correlative attention to elementary details. The inclusion of a few more pages of well-organized and concisely presented "introductory" material for the beginner might very well have made the book more valuable without detracting from its worth to the advanced student and graduate research worker.

The physical make-up of the volume does not appear to be up to the usual high standards of the publishers. Numerous illustrations are weakly and unevenly imprinted. The cloth binding is thin and easily worn.

This book is heartily recommended as the best text available in its field to date, however. To no less an extent is it a valuable reference work. It should do much to encourage the appearance of more courses in comparative physiology in college curricula. It is hoped that the writers will keep abreast with current and future physiological research by revisions of their text from time to time.

W. S. NEWCOMER

Department of Physiology
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BRIEFLY REVIEWED

The Nininger Collection of Meteorites. H. H. Nininger and Addie D. Nininger. 144 pp. Illus. \$3.00, plus postage. American Meteorite Museum, Winslow, Ariz. 1950.

THROUGH education and intensive field work, Dr. H. H. Nininger and his wife have been responsible for the discovery of more meteorites than any other persons in history, and it is quite likely that their record will go unchallenged for many decades to come. In addition, the Niningers have built up a private meteorite collection that is one of the largest and most interesting in the world. Represented in the collection are 587 individual meteorites, including 145 main masses. This small book consists primarily of an itemized accounting of the Nininger collection, and as such it should be of considerable interest to everyone engaged in meteorite

research. The book is, however, more than just a straightforward listing, for within its pages are represented the fruits of thirty years of hard and often courageous work, financed not by endowments, but by ingenuity.

The book contains, in addition to the catalogue listing, a brief history of the development of the Nininger collection, a series of maps showing the location of the meteorite finds for which they were directly or indirectly responsible, 15 pages of field notes, and 34 pages of plates that are, in the main, of high quality. The principal deficiency of the catalogue is that unfortunately no references to the scientific literature are given.

The record of the Nininger discoveries, both direct and indirect, is a long one. In thirty years they have increased the number of known Nebraska meteorites from 9 to 29. They were responsible for the discovery of 26 meteorites in Texas, 28 in Colorado, 37 in Kansas, and 9 in Wyoming. When we remember that in a year, over the whole surface of the earth, only about 10 meteorites are seen to fall, the accomplishments of the Niningers are indeed noteworthy. It seems clear that for many years to come science will reap benefits from their efforts.

HARRISON S. BROWN

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Lifelong Boyhood. Loye Miller. ix + 226 pp. Illus. \$2.75. University of California Press, Berkeley, 1950.

DR. MILLER'S lifelong boyhood has spanned a remarkable time in the development of biology in the West. This is well illustrated by two incidents selected from many similar ones cited in his book. The first of these is a reference to a potential encounter with renegade Apaches, and the second a reference to the ready way in which Professor Joseph Le Conte produced funds for university research in the form of gold pieces from his pants pocket. Readers will all agree that modern work in biology is no longer conducted with associations like these.

Lifelong Boyhood is not an attempt at a complete autobiography, but rather represents a series of accounts selected from the author's field experiences in ornithological and paleontological work. Outstanding are the sections dealing with the discovery and excavation of the La Brea tar pits, a trip to the John Day Basin, and an expedition to Baja California. In addition to autobiographical sections, the book includes a series of the author's reprinted papers, which augment the stories of his personal experiences.

Younger generations of naturalists should especially enjoy Dr. Miller's book, not only because of its style, but particularly because only through autobiographical presentations such as this can they become acquainted with the personalities and experiences that have carried biology to its present-day development.

JOHN CUSHING

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LETTERS

MARS

When Giovanni Schiaparelli
Turned his sights upon the stars,
He stopped to scan the glowing belly
Of ruddy Mars.

He charted the seas and polar caps,
And then by way of a grand finale,
He plotted upon his Martian maps
A long *canale*.

A "channel" was what he had observed,
As all could tell who spoke Italian,
But the course of science was sharply swerved
By some rapscallion,

Who freely rendered the word to suit
His public's wild imaginings;
"Canals!" he screamed, and that, to boot,
Meant living things.

When any rumor is once imbibed
All antidotes prove ineffectual,
And Martian men were soon described
As intellectual.

The rabid press spread wild confusion,
Weaving Sunday Supplement spells,
And this finally led to the grand illusion
Of Orson Welles.

Thus Mars, who never planned assault,
Is eyed from Earth with trepidation,
Victim, through no intrinsic fault,
Of poor translation.

S. C. FLORMAN

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THE fact that Professor Harry J. Fuller's article, "The Emperor's New Clothes, or *Prius Dementat*," is provoking some lively discussion is all to the good. As an educator who for more than thirty years has tried to bear arms against the rising tide of illiteracy among our undergraduates, I agree enthusiastically with Dr. Fuller's premise and conclusions.

A few years ago I employed in a junior college a "professionally trained" teacher of English literature, who implored me to tell her how many lines of *Lycidas* she should compel herself to read in order to impart their meaning to her pupils. I am therefore no longer surprised when my own students come to me with an all but indelible hatred of the "classics" whose acquaintance they made through the "communication situations" created by our present "scientific" educational system.

Dr. Fuller and I may possibly be wrong. There may be other reasons to account for the small Latin and feeble English at the command of students who now hope to make their way in highly competitive professional areas. But we must all consider seriously the problems which Dr. Fuller has raised. Let a qualified member of the opposite camp reply *in extenso* to his arguments; and may he do so, if he can, with comparable lucidity, pertinence, and wit.

ERNEST BRENNEMECKE

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HARRY J. FULLER, author of the recent SCIENTIFIC MONTHLY article "The Emperor's New Clothes" (72, 32 [1951]), will speak in Wilmington, Delaware, at a meeting of the Ursuline Academy Home & School Association on Monday, May 7. The meeting is open to the public, and will be held at 8:15 P.M. in the Ursuline Academy Auditorium on Franklin Street near Pennsylvania Avenue. Dr. Fuller will present the current version of "The Emperor's New Clothes."*

SYDNEY STEELE

*Atlas Powder Company
Wilmington, Delaware*

* Dr. Fuller spoke on the same theme before the Phi Beta Kappa chapter at the University of Oklahoma, Norman, on April 24, and on October 19 he will speak before the Cleveland Regional Council of Science Teachers. THE SCIENTIFIC MONTHLY will furnish free reprints (up to six to one person) of the article by Dr. Fuller that appeared in the January 1951 issue.

